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International Labour Organization

# Local investments for climate change adaptation

## Green jobs through green works

Regional Office for Asia and Pacific

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## Green jobs through green works

A guide for identifying, designing and implementing interventions in support of climate change adaptation at the local level

Regional Office for Asia and the Pacific

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# Foreword

When the term “climate change” is used these days, most people relate it to mitigation and interventions to stop global warming. Climate change, however, is occurring now and further changes are inevitable. The effects of the changing climate are already felt around the world. Helping affected communities and especially poor communities to adapt now to these changing weather patterns is necessary to reduce future impacts on their livelihoods and living conditions.

Infrastructure will play a major part in local adaptation to climate change. New and additional investments in infrastructure will be needed to help affected communities to reduce the impacts. Equally, infrastructure will need to be built to higher standards and improved designs will be needed to better withstand the local impacts of climate change. There are three main areas for adaptation in this regard. The first is irrigation and water and land resource management in rural areas, so that the variability and intensity of water can be controlled and the quality of existing land can be improved. The second is flood control, protection and drainage and water conservation structures in both rural and urban areas and that will need to be designed to deal with the variability and frequency of water availability. The third is rural transport infrastructure because rural roads need to be constructed to withstand the increased level of rainfall and flooding. The local institutions and procedures to deal with such interventions are often weak or do not have the capacity to deal with the required changes. Capacity building will constitute a key component in any programme that seeks to address climate change at the local level.

A local resource-based approach to infrastructure development can be a major contribution to assisting communities adapt to climate change. The use of local resources and green technologies will make a positive contribution towards the environment. The International Labour Organization has developed such a local resource-based approach and demonstrated a range of tools that can be used in the planning, preparing and implementing of local infrastructure works. Guidelines and training manuals are also available for capacity building of the public and private sectors to deliver infrastructure investments through local resource-based approaches. Activities generally take place within the context of rural development, urban low-income settlement upgrading and crisis response. There is a need now to place this work in the context of climate change adaptation. The ILO is working on such an approach and this guide is an output of that effort.

The guide describes the approach in the context of climate change adaptation and identifies the benefits for poor communities. It links climate change adaptation with poverty reduction and employment creation. The guide contains three general sections on the context and the approach and five technical sections that identify possible climate change adaptation works in five subsectors: irrigation, soil and water conservation, flood control, rural transport and forestry. It elaborates on the local resource-based approach and demonstrates how green jobs can be created through green works.

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1

# Climate change

# Climate change





## 1.1 Introduction

The climate is changing. Some areas are experiencing longer and more pronounced droughts; other areas receive more storms and rains and experience increased flooding. Some hard-hit areas are suffering from both. Higher temperatures are behind these changes.

The phenomenon behind the increase in the earth's temperature is called the greenhouse effect. Gases, such as water vapour, carbon dioxide and methane, form a filter that ensures that more of the sun's energy remains in the earth's atmosphere. Increasing emissions of carbon dioxide, methane and other gases have made – and continue to make – the filter of greenhouse gases thicker, meaning that more energy remains in the atmosphere. This leads to higher temperatures. Since the end of the nineteenth century, the mean temperature has increased by 0.6°C. When the mean global temperature rises, this affects the climate.

In this guide we start from the basis that climate change is a reality. We will not therefore be concerned with a detailed assessment of evidence demonstrating the phenomenon. Nor indeed will we spend much space discussing the reasons for climate change. It is a fact that the climate is already becoming more extreme, with storms becoming more severe, heat waves hotter and more frequent, and rain increasing in volume and density. The effects are already clear. The impacts are all around us. The polar ice caps and other permanent ice sheets are melting, which is leading to higher sea levels. Desert areas are becoming larger, and species of animals and plants are migrating or becoming extinct because they are unable to survive under the new conditions.

In Asia and the Pacific the indications of climate change are evident. An Asian Development Bank study has shown that in the period from 1960 to 2008, the number of storms and floods in Indonesia, Philippines,[1] Thailand and Viet Nam rose significantly (table 1). From 2000 to 2008, the annual number of floods and storms rose from 23 to 58 in Indonesia and from 34 to 60 in Viet Nam.

1 In the Philippines, the frequency of typhoons increased more than four-fold during 1990–2003.

Table 1.1: Number of floods and storms in South-East Asia, 2000 and 2008

| | Indonesia | Philippines | Thailand | Viet Nam |
|---|---|---|---|---|
| 2000 | 23 | 15 | 32 | 34 |
| 2008 | 58 | 116 | 38 | 60 |

An Oxfam research study has shown that, globally, the number of people affected by climate related disasters has almost quadrupled since 1980.[2]

In India, some 20 per cent of the total land area is susceptible to drought. The frequency of drought has increased over the past 50 years. Between 1900 and 1950 there were six periods, in the following 50 years there were 12. In contrast, four have already occurred in the first eight years of the twenty-first century. Drought has a massive impact on income in the country. Marginal farmers can expect a 40 per cent decrease in monthly income. Flooding is also on the increase in India, as the 2007 floods attest. Fifty years ago, flooding covered an area of 19 million hectares; by 2003 this had increased to 40 million, about 12 per cent of India's area.

***Bangladesh***

*The 1998 flood, one of the worst in recent memory, is an example of how vulnerable Bangladesh is to flooding. The flood was the result of three factors: i) heavy rainfall and snowmelt in India and Nepal, ii) a 20 per cent increase in rainfall in Bangladesh in the catchment areas of its major rivers (the Ganges and Brahmaputra) and more than double the rainfall in the Meghna and iii) elevated tides in the Bay of Bengal from the monsoon. More than 30 million Bangladeshis were displaced, with 20 million rendered homeless – a national catastrophe.*

Over the course of July and August 2010, Pakistan experienced the worst monsoon floods in living memory.

Bangladesh is subject to severe flooding each year. One-fifth of the country is flooded annually. Estimates suggest that the catastrophic flood of 1998 (see box) could well be repeated on a more frequent basis. This will be due to higher rates of precipitation, stronger cyclones and higher sea levels.[3]

The reaction to the recognition of climate change falls into two categories. The first is to identify ways in which climate change can be reduced or

2 Global natural disaster occurrence and impact 1980–2007, from the Centre for Research on the Epidemiology of Disasters and Emergency Events Database; see W. Diamond and S. Ganeshan: *The right to survive: The humanitarian challenge for the twenty-first century* (Oxford, Oxfam International, April 2009).

3 Organisation for Economic Co-operation and Development (OECD): *Development and climate change in Bangladesh* (2003).

mitigated. The discussions on how to reduce the production of greenhouse gases and on the attempts to develop systems of carbon marketing fall into the category of mitigation. Unfortunately, there seems to be a general consensus that even if these mitigation measures are successful, they will not be enough to halt the changes in climate.

The second category is concerned with adaptation. Given that floods, storms and drought are to become more serious, what can be done to adapt to these increasingly severe climate-related events?

Both the mitigation of and the adaptation to climate change are areas that have received considerable attention in recent times. Much of this has been concerned with policy and technological innovation to both limit and adapt to climate change. This is certainly necessary.

It is clear that the effect of climate change will fall disproportionately on those who have had little involvement in producing the problem – the poor. The poor depend substantially on the natural world for their survival and are therefore more vulnerable to changes in their natural environment.[4]

The first message of this guide is that local communities and organizations need to be empowered to adapt to climate change. This is not merely a question of providing them with tools and technologies. It is a question of raising awareness of the changes that are occurring and will occur. It means developing planning systems which take into account the change. Local institutions will need to be strengthened so that they can respond to the changes. Communities need access to local resource-based solutions that allow them to effectively deal with the changes that will take place.

**Indonesia**

*A local farmer says: "People here don't talk about climate change. I have read it somewhere in a book or in a newspaper, but I don't really know what it means."*

*A senior adviser to the Indonesian environment minister says: "The climate change issue is more perceived as an international issue rather than a domestic issue. We need to start with the decision makers, the planners and also those who can approve the budgets – including the parliament –because we need to address this awareness campaign. And that will require substantial allocations of the national budget."*

Source: BBC

The second message is that recurring natural calamities need to be seen as part of the natural order of things, not, as is presently the case, as intermittent disasters

4 Desmond Tutu described this situation as drifting into a world of "adaptation apartheid".

that are dealt with through crisis measures. Each year there are recurring natural disasters around the world – floods in Bangladesh and Viet Nam, typhoons in the Philippines. These events generally produce a crisis response on behalf of the government and the donor community. They are dealt with as if they are extraordinary events which only happen infrequently. The most conservative predictions however suggest that such "disasters" will become commonplace and increasingly frequent. It is therefore necessary to plan for them and, to the extent possible, provide measures to both reduce, and adapt to, their impact.

Table 1.2: Summary of observed and present climate trends and variability

| Region | Country | Change in temperature | Change in precipitation | References |
|---|---|---|---|---|
| North Asia | Russia | 2–3°C rise in past 90 years, more pronounced in spring and winter | Highly variable, decrease during 1951 to 1995, increase in last decade | Savelieva et al., 2000; Peterson et al., 2002; Gruza and Rankova, 2004 |
| | Mongolia | 1.8°C rise in last 60 years, most pronounced in winter | 7.5% decrease in summer and 9% increase in winter | Batima et al., 2005a; Natsagdorj et al., 2005 |
| Central Asia | Regional mean | 1 to 2°C rise in temperature per century | No clear trend during 1900 to 1996. | Peterson et al., 2002 |
| | North-West China | 0.7°C increase in mean annual temperature from 1961 to 2000 | Between 22% and 33% increase in rainfall | Shi et al., 2002 |
| Tibetan Plateau | Regional mean | 0.16 and 0.32°C per decade increase in annual and winter temperatures, respectively | Generally increasing in north-east region | Liu et al., 1998; Yao et al., 2000; Liu and Chen, 2001; Cai et al., 2003; Du and Ma, 2004; Zhao et al., 2004 |
| West Asia (Middle East) | Iran | From 1951 to 2003, several stations in different climatologically zones reported significant decrease in frost days due to rise in surface temperature | Some stations show a decreasing trend in precipitation (Anzali, Tabriz, Zahedan) while others (Mashad, Shiraz) have reported increasing trends | IRIMO, 2006a, b; Rahimzadeh, 2006 |
| East Asia | China | Warming during last 50 years, more pronounced in winter than summer, rate of increase more pronounced in minimum than in maximum temperature | Annual rain declined in past decade in the North-East and northern China, increase in western China, Changjiang River and along south-east coast | Zhai et al., 1999; Hu et al., 2003; Zhai and Pan, 2003 |
| | Japan | About 1.0°C rise in twentieth century, 2–3°C rise in large cities | No significant trend in the twentieth century although fluctuations increased | Ichikawa, 2004; Japan Meteorological Agency, 2005 |
| | Republic of Korea | 0.23°C rise in annual mean temperature per decade, increase in diurnal range | More frequent heavy rain in recent years | Jung et al., 2002; Ho et al., 2003 |

| Region | Country | Change in temperature | Change in precipitation | References |
|---|---|---|---|---|
| South Asia | India | 0.68°C increase per century, increasing trends in annual mean temperature, warming more pronounced during post-monsoon and winter | Increase in extreme rains in the North-West during summer monsoon in recent decades, lower number of rainy days along east coast | Kripalani et al., 1996; Lal et al., 1996; Lal et al., 2001b; Singh and Sontakke, 2002; Lal, 2003 |
| | Nepal | 0.09°C per year in Himalayas and 0.04°C in Terai region, more in winter | No distinct long-term trends in precipitation records for 1948 to 1994 | Shrestha et al., 2000; Bhadra, 2002; Shrestha, 2004 |
| | Pakistan | 0.6 to 1.0°C rise in mean temperature in coastal areas since early 1900s | 10 to 15% decrease in coastal belt and hyper arid plains, increase in summer and winter precipitation over the last 40 years in northern Pakistan | Farooq and Khan, 2004 |
| | Bangladesh | An increasing trend of about 1°C in May and 0.5°C in November during the 14-year period from 1985 to 1998 | Decadal rain anomalies above long-term averages since 1960s | Mirza and Dixit, 1997; Khan et al., 2000; Mirza, 2002 |
| | Sri Lanka | 0.016°C increase per year between 1961 and 1990 over entire country, 2°C increase per year in central highlands | Increase trend in February and decrease trend in June | Chandrapala and Fernando, 1995; Chandrapala, 1996 |
| South-East Asia | General | 0.1 to 0.3°C increase per decade reported between 1951 to 2000 | Decreasing trend between 1961 and 1998; number of rainy days have declined throughout South-East Asia | Manton et at., 2001 |
| | Indonesia | Homogeneous temperature data were not available | Decline in rainfall in southern and increase in northern regions | Manton et al., 2001; Boer and Faqih, 2004 |
| | Philippines | Increase in mean annual, maximum and minimum temperatures by 0.14°C between 1971 and 2000 | Increase in annual mean rainfall since 1980s and in number of rainy days since 1990s, increase in inter-annual variability of onset of rainfall | PAGASA, 2001; Cruz et al., 2006 |

Source: IPCC

Table 1.3: Summary of observed changes in extreme events and severe climate anomalies

| Country/region heatwaves | Key trend | Reference |
|---|---|---|
| Russia | Heatwaves broke past 22-year record in May 2005 | Shein, 2006 |
| Mongolia | Heatwave duration has increased by 8 to 18 days in last 40 years; coldwave duration has shortened by 13.3 days | Batima et al., 2005a |
| China | Increase in frequency of short duration heatwaves in recent decade, increasing warmer days and nights in recent decades | Zhai et al., 1999; Zhai and Pan, 2003 |
| Japan | Japan Increasing incidences of daily maximum temperature >35°C, decrease in extremely low temperature | Kawahara and Yamazaki, 1999; Japan Meteorological Agency, 2005 |
| Korea | Increasing frequency of extreme maximum temperatures with higher values in 1980s and 1990s; decrease in frequency of record low temperatures during 1958 to 2001 | Ryoo et al., 2004 |
| India | Frequency of hot days and multiple-day heatwave has increased in past century; increase in deaths due to heat stress in recent years | De and Mukhopadhyay, 1998; Lal, 2003 |
| South-East Asia | Asia Increase in hot days and warm nights and decrease in cold days and nights between 1961 and 1998 | Manton et al., 2001; Cruz et al., 2006; Tran et al., 2005 |
| Intense rains and floods | | |
| Russia | Increase in heavy rains in western Russia and decrease in Siberia; increase in number of days with more than 10 mm rain; 50 to 70% increase in surface runoff in Siberia | Gruza et al., 1999; Izrael and Anokhin, 2001; Ruosteenoja et al., 2003; Gruza and Rankova, 2004 |
| China | Increasing frequency of extreme rains in western and southern parts including Changjiang river, and decrease in northern regions; more floods in Changjiang river in past decade; more frequent floods in North-East China since 1990s; more intense summer rains in East China; severe flood in 1999; seven-fold increase in frequency of floods since 1950s | Zhai et al., 1999; Ding and Pan, 2002; Zhai and Pan, 2003; Zhai, 2004 |
| Japan | Increasing frequency of extreme rains in past 100 years attributed to frontal systems and typhoons; serious flood in 2004 due to heavy rains brought by 10 typhoons; increase in maximum rainfall during 1961 to 2000 based on records from 120 stations | Kawahara and Yamazaki, 1999; Isobe, 2002; Kajiwara et al., 2003; Kanai et al., 2004 |
| South Asia | Serious and recurrent floods in Bangladesh, Nepal and north-east states of India during 2002, 2003 and 2004; a record 944 mm of rainfall in Mumbai, India on 26 to 27 July 2005 led to loss of over 1,000 lives with loss of more than US$250 million; floods in Surat, Barmer and in Srinagar during summer monsoon season of 2006; 17 May 2003 floods in southern province of Sri Lanka were triggered by 730 mm rain | India Meteorological Department, 2002 to 2006; Dartmouth Flood Observatory, 2003. |
| South-East Asia | Increased occurrence of extreme rains causing flash floods in Vietnam; landslides and floods in 1990 and 2004 in the Philippines, and floods in Cambodia in 2000 | FAO/WFP, 2000; Environment News Service, 2002; FAO, 2004a; Cruz et al., 2006; Tran et al., 2005 |

| | | |
|---|---|---|
| **Droughts** | | |
| Russia | Decreasing rain and increasing temperature by over 1°C have caused droughts; 27 major droughts in 20th century have been reported | Golubev and Dronin, 2003; Izrael and Sirotenko, 2003 |
| Mongolia | Increase in frequency and intensity of droughts in recent years; droughts in 1999 to 2002 affected 70% of grassland and killed 12 million livestock | Batima, 2003; Natsagdorj et al., 2005 |
| China | Increase in area affected by drought has exceeded 6.7 Mha since 2000 in Beijing, Hebei Province, Shanxi Province, Inner Mongolia and North China; increase in dust storm affected area | Chen et al., 2001; Yoshino, 2000, 2002; Zhou, 2003 |
| South Asia | 50% of droughts associated with El Niño; consecutive droughts in 1999 and 2000 in Pakistan and N-W India led to sharp decline in watertables; consecutive droughts between 2000 and 2002 caused crop failures, mass starvation and affected ~11 million people in Orissa; droughts in N-E India during summer monsoon of 2006 | Webster et al., 1998; Lal, 2003; India Meteorological Department, 2006 |
| South-East Asia | Droughts normally associated with ENSO years in Myanmar, Laos, Philippines, Indonesia and Vietnam; droughts in 1997 to 98 caused massive crop failures and water shortages and forest fires in various parts of Philippines, Laos and Indonesia | Duong, 2000; Kelly and Adger, 2000; Glantz, 2001; PAGASA, 2001 |
| **Cyclones/typhoons** | | |
| Philippines | On an average, 20 cyclones cross the Philippines Area of Responsibility with about 8 to 9 landfall each year; with an increase of 4.2 in the frequency of cyclones entering PAR during the period 1990 to 2003 | PAGASA, 2001 |
| China | Number and intensity of strong cyclones increased since 1950s; 21 extreme storm surges in 1950 to 2004 of which 14 occurred during 1986 to 2004 | Fan and Li, 2005 |
| South Asia | Frequency of monsoon depressions and cyclones formation in Bay of Bengal and Arabian Sea on the decline since 1970 but intensity is increasing causing severe floods in terms of damages to life and property | Lal, 2001, 2003 |
| Japan | Number of tropical storms has two peaks, one in mid 1960s and another in early 1990s, average after 1990 and often lower than historical average | Japan Meteorological Agency, 2005 |

Source: IPCC



## 1.2 Implications

### Climate change impacts the poor the most

The effects of climate change are visible everywhere. In the Asia-Pacific region crop yields have declined, partly due to rising temperatures and extreme weather events. Increasing temperatures and rainfall variability in Central, East, South and South-East Asia have increased disease and heat stress. High levels of gross domestic product (GDP) growth are in danger of being nullified when the economic impact of climate change is taken into account.

The Stern Report[5] suggests that in many developing countries, the capacity of poor people to withstand extreme weather events, such as a drought, is constrained both by low income levels and by limited access to credit, loans or insurance. These problems are likely to become worse with climate change as wet and dry seasons become increasingly difficult to predict.

Moreover, reduced crop yields, decreased cultivable land and limited physical access will lead to higher levels of unemployment and the loss of livelihoods.

***South Asia***

*Crop yields could decrease up to 30 per cent in central and south Asia by the mid twenty-first century. Endemic morbidity and mortality are expected to rise due to diarrheal disease primarily associated with floods and droughts.*

*Freshwater availability, particularly in large river basins, is projected to decrease, which, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion people by 2050.*

Source: IPCC

5 N. Stern: *Stern review: The economics of climate change* (Cambridge, Cambridge University Press, 2006).

Many countries have weak social safety nets that leave the poorest people even more vulnerable to climate shocks. Low-income countries, such as Cambodia, Lao People's Democratic Republic and Nepal, have limited financial reserves to cushion the economy against natural disasters. In addition, their underdeveloped financial markets and weak links to world financial markets limit the ability to diversify risk or obtain financial resources. A telling statistic is that in low-income countries less, than 1 per cent of the total losses from natural disasters were insured during the period 1985 to 1999.

Climate change is already having a serious impact. In the future it will have dramatic effect on the natural environment and consequently on people. The severest effects will be visited upon those who are in the weakest position to deal with the changes. The poor have limited resources, little access to information and they need to protect their own survival strategies while at the same time dealing with the need for adaptation

***East Asia***

*If the world continues with business as usual, Indonesia, Philippines, Thailand and Viet Nam could experience combined damages equivalent to more than 6 per cent of their GDP products every year by the end of this century, dwarfing the costs of the current financial crisis.*

Governments and donor agencies can of course assist in providing policies and strategies that will support adaptation. Nevertheless, the onus of the practical response will be laid upon communities and local organizations.

Inadequate resources and poor governance often result in poor provision of public services. Those services that would help to manage and cope with the effects of climate change – such as early warning systems for extreme weather, programmes to raise awareness of climate change, land and water resource management and programmes to control diseases spread by vectors – receive limited attention in many of the countries of the region.

## Impact

In this section we look at different thematic areas to assess the major implications. This will provide an indication of how communities can adapt to the foreseen implications of climate change.

## Water supply

Water supply is affected by three main factors – increasing temperature, variable rainfall and the rise of sea levels.

Increased temperature causes increased evaporation in rivers, dams and other water reservoirs, leading to decreased water availability for human consumption, irrigation and hydropower generation.

Variable rainfall has major effects. It results in a decrease in river flows and the water level in many dams and water reservoirs, leading to decreased water availability. Many more people will have decreased access to water. In addition, an increase in runoff results in soil erosion and flooding, which also affects the quality of surface and groundwater.

The rise in sea levels results in the need to strengthen sea defences in coastal areas. In addition, the increase in saltwater intrusion into aquifer and groundwater resources also leads to decreased freshwater availability.

Overall, the impact of climate change on water supply will be felt in a reduction in the availability of water, the over topping of coastal sea defences and the increased risk of soil erosion and flooding.

In Indonesia, ENSO[6] events have significantly affected river flows and water reservoirs. Flow data from 52 rivers across the country show a significant increase in the number of rivers in which minimum flow was caused by drought. Similarly, the number of rivers in which the peak flow caused floods has also significantly increased.[7]

In the Philippines, rising sea levels have aggravated the already water-stressed areas.[8]

In Singapore, rising global temperatures have changed rainfall patterns, which affect the amount of water collected and stored in reservoirs.

In Thailand, with the onset of climate change, the water balance has become a common annual problem. Changes in rainfall patterns and the frequency and intensity of rainfall have affected the quantity and quality of water resources from some watersheds.[9]

In Viet Nam, the increase in evapo-transpiration (loss of water from the soil both by evaporation and transpiration by plants) due to increased temperature has reduced the availability of water for irrigation and other purposes.[10]

## Agriculture

Almost half the world – over three billion people – lives on less than US$2.50 a day. The majority of them live in rural areas. Their livelihoods depend on smallholder agriculture and farm employment. This same group of people also accounts for most of the 925 million people in the world who are undernourished.[11] Agricultural production underpins many national economies, and farming is often the main occupation of the rural poor.

6 El Niño-Southern Oscillation is a global ocean-atmosphere phenomenon.

7 I. Las et al.: *Analysis of probability of climate variability and water availability in Indonesia* (Bogor, 1999).

8 R. Perez: *Philippines country report – A regional review on the economics of climate change in Southeast Asia* (Manila, Asian Development Bank, 2008).

9 S. Jesdapipat: *Thailand country report – A regional review on the economics of climate Change in Southeast Asia* (Manila, ADB, 2008).

10 N. Cuong: *Vietnam country report – A regional review on the economics of climate change in Southeast Asia* (Manila, ADB, 2008).

11 Food and Agriculture Organization of the United Nations (FAO): *The state of food insecurity in the world 2010* (Rome, 2010).

The Intergovernmental Panel on Climate Change (IPCC) predicts that agricultural production will decrease over the coming decades. This will have serious impacts on the national economies. Further, the impact on agriculture will have important multiplier effects, particularly on employment. Losses of productivity linked to climate change will increase inequalities between rain-fed and commercial producers, undermine livelihoods and add to pressures that are leading to forced migration.

Table 1.4: Agriculture in East and South Asia

| | Agriculture as percentage of GDP | Agricultural labour force as a percentage of total |
|---|---|---|
| East Asia | 10 | 58 |
| South Asia | 17 | 55 |

As can be seen from table 1.4, agriculture is a modest contributor to GDP. However, more than 50 per cent of the labour force in East and South Asia is employed in agriculture. Consequently, climate change will have an increasing and major impact on rural unemployment. Reduced income from employment compromises efforts on poverty reduction. Reduced income will impact on the level of attendance at schools and the ability to deal with outbreaks of disease.

India, for example, is a high-growth economy. However, the benefits have been unequally shared. Around 28 per cent of the population, some 320 million people, live below the poverty line, with three-quarters of the poor in rural areas. Unemployment among rural labourers, one of the poorest groups, is increasing, and almost half of rural children are underweight for their age. Superimposing the effects of climate change on this situation will only exacerbate the existing difficult situation.

It is predicted that heat stress, drought, climate-associated pests and diseases, flooding and typhoons will all contribute to the decline in the production of rice, maize, soybean and other crops. Industrial crops, such as oil palms and rubber, coconut and fruit trees, will also be at risk due to heat stress and drought as well as wildfires. Consequently, the decline in grain production and industrial crops will have an impact on the livestock industry and emerging industries, which are very much dependent on natural resources. A rise in sea levels will also claim fertile agriculture land near coastal areas due to erosion and reduce arable lands through soil salination.

Rising temperatures will also lead to a reduction in fish production. In South-East Asia, this will seriously affect the region's potential as the world's largest producer of fish and marine products.

In summary, increasing temperature will result in decreased crop yields and increased livestock deaths due to heat stress and increased outbreaks of insect pests and diseases. Increased rainfall will mean increased frequency of floods and tropical cyclones causing damage to crops. The change in rainfall patterns will affect current cropping patterns, crop-growing seasons and sowing periods. In addition, increased runoff and soil erosion will cause a decline in soil fertility and consequently crop yields. The rise in sea levels will result in the loss of arable lands due to inundation, and the salination of irrigation water will affect crop growth and yield.

## Health

Some of the possible direct threats that climate change could pose on human health include morbidity and mortality due to thermal stress, vector-borne infectious diseases (such as malaria and dengue), diarrhoea and malnutrition. Indirectly, climate change could cause injury, and in the worst case, deaths, as a result of landslides, flash floods and tropical cyclones.

Respiratory diseases brought about by worsening air pollution (such as from forest fires) and ill health due to social dislocation and migration could be attributed indirectly to climate change.


In South-East Asia, increased dengue outbreaks and malaria cases are reported to be strongly correlated with the El Niño years. Dengue cases in Indonesia increased significantly in La Niña years, when seasonal rainfall increased above normal.

A 1998 study in the Philippines found that non-infectious diseases, such as shellfish poisoning, cardiovascular diseases and respiratory problems, are affected by climate change, variability and extremes.[12]

Outputs of dengue fever are indicative of the problem. In Singapore, dengue outbreaks happen in cycles, peaking every six to seven years. During the last peak, in 2005, 14,209 people were infected and 25 died. That year's total was almost three times the previous peak of 5,258 in 1998. Dengue fever has become an annual epidemic in the plains and central coast of Viet Nam. The outbreaks are closely associated with the El Niño phenomenon.

## Forestry

Forests have four major roles in climate change: i) they currently contribute about one-sixth of the global carbon emissions when cleared, overused or degraded; ii) they react sensitively to a changing climate; iii) when managed sustainably, they produce wood fuels as a benign alternative to fossil fuels; and iv) they have the potential to absorb about one-tenth of global carbon emissions projected for the first half of this century into their biomass, soils and products and store them – in principle, in perpetuity.

The impact of the increased temperature leads to higher frequency of forest fires and the increase in infestation of pests and therefore disease. The variation of rainfall also results in increased forest fire, and pest and disease infestation due to drought. It also affects the survival of seedlings and saplings. Further, it results in increased soil erosion and degradation of watershed due to intermittent drought and flooding. The sea level rise leads to the loss of mangrove forests.

12 Paraso Flavier and Baylon: *Addressing climate change: Perspective from health – Proceedings of the Environmental Protection and Management Conference* (1998).

## Coastal erosion

Coastal flooding and erosion have been accelerated by the destabilization of coastlines due to advancing sea levels and the increase in extreme events (such as El Nino and tropical cyclones). The tropical cyclones that hit South-East Asia in recent years, together with storm surges, have accelerated the erosion of beaches, deltas and mangrove swamps. This has led to substantial economic losses, loss of lands and even the premature death of inhabitants.

Rising sea levels have caused saltwater intrusion into coastal freshwater and groundwater resources in many areas of South-East Asia, aggravating water shortages brought about by declining rainfall. Rising sea levels have also accelerated inundation and land subsidence in coastal cities and communities. Examples can be found all over the Pacific Islands. This has also resulted in considerable losses to tourism and aquaculture industries. For example, Thailand's 2,667 kilometres of shoreline is under serious threat from coastal erosion, which is occurring at the rate of 15–25 metres per year in some places.

## Urban areas

Over the next few decades, another two to three billion people will be added to the world's population, virtually all of them in developing countries. According to the Stern report, the number of people living in cities in developing countries is predicted to rise from 43 per cent in 2005 to 56 per cent by 2030.[13] The biggest cities will be found in the developing world. Many people migrating to cities will live in poor conditions, often on marginal land. They will be particularly vulnerable because of their limited access to clean water and sanitation and their location in flood-prone areas.

Flooding is already a major problem in the urban areas of many developing countries. This is caused by a variety of factors. Local flooding occurs many times a year in slum areas because there are few drains, most of the ground is highly compacted and pathways between dwellings become streams after heavy rain. Drains and culverts that do exist are often blocked by waste and debris. With the increase in precipitation and the demand from the increased population, the current situation will get worse. Small streams in urban areas rise quickly after heavy rain but often pass through culverts that are inadequate. The result is that these culverts and drainage channels cannot deal with the increased flow.

13 N. Stern: *Stern review: The economics of climate change* (Cambridge, Cambridge University Press, 2006).

Major rivers flowing through urban areas are affected by land use changes and engineering works upstream. Dams can trap sediment, causing rivers to erode their banks downstream. Dam operations may lead to high flows when stored water is released suddenly.

Often, urban growth has expanded over some of the flood plain, making parts of the city below flood level and reducing the area into which floods can naturally overflow. In addition, in lowland and coastal cities, wet-season flooding may affect some areas for two or more months. This is because rain and river water combine to raise the levels of water in swamps that would have naturally been inundated at certain times of the year. Dumping of waste beneath dwellings in these areas tends to help raise levels further.

Sanitation in many of the developing world's major cities is presently basic at best. The predicted increase in flooding will therefore lead to an increase in the risk of water-borne diseases, such as cholera. While the increase in rainwater should mean greater access to clean water, there will need to be a major increase in the infrastructure required to effectively capture this water for potable use.

### Rural transport

Rural roads feed into the main road network and link rural communities to population centres, health facilities and markets. Rural roads are often facilitators; they facilitate rural and agricultural development in that they improve mobility and accessibility. The main benefits often come from traders, transport service operators and extension workers. It is important to differentiate between areas with relatively good access and areas with relatively poor or no road access. In areas with relatively good road access, the most important objective is to sustain those levels of access (and if necessary, improve to even greater levels). A key issue in the effort to sustain this access is protecting local roads in areas affected by climate change. Existing roads need to be climate proofed.

Road embankments are built to support a road or as protection against flooding. The appropriate embankment height is considered to be 0.5 metres above the level to which the surrounding terrain floods. Flooding patterns in many areas, however, are changing due to a wetter climate. Roads may have to be built on embankments or existing embankments may have to be raised to continue to protect the road. This requires a major investment in many areas. The protection of roads against flooding also requires an increased capital outlay for structures such as drains retention walls, culverts and bridges. By reducing the flow of water, it is possible to reduce the possible damage to the roads as a result of climate change.

## 1.3 Adapting to climate change

A great deal has been written about what governments and donor agencies can do to help developing countries adapt to climate change. Much of the literature is concerned with analytical work, assessing the cost of such adaptation measures and developing systems and procedures that provide countries with an overall framework for adaptation.

The National Adaptation Programmes of Action (NAPAs), financed by the Global Environment Fund's Least Developed Countries Fund, are among the practical products of multilateral cooperation on adaptation. NAPAs are intended to identify urgent and immediate needs while at the same time developing a framework for bringing adaptation into the mainstream of national planning. While this is a step in the right direction, NAPAs have been criticized as inadequately financed, that the costs are generally underestimated and that there is a tendency to focus on projects rather than programmes.

The first point to stress regarding the adaptation to climate change is that the most

severely affected are the poor who have the least capacity to respond. Nevertheless, in former times when there was limited formalized support, communities and local groups always responded to major environmental shocks. Through years of development aid and donor support, there has been a tendency to view the poor as those requiring the aid that governments and the international community can provide. This has resulted in aid dependency and a plethora of programmes that base their inputs on the perceived demand of the recipients. This is not to say that such inputs are not required or appreciated; but it's necessary to keep in mind that the capacity of communities to assess their situation and to make the necessary effort to improve it is often grossly underestimated.

The second point is that climate change adaptation is not the same as disaster relief. It needs to be an integral part of national policies and strategies. Moreover, because adaptation is inherently local, much depends on the capacity of communities to respond to climate change. This has far-reaching consequences in terms of participation, planning, information flow and fund allocation.

Adaptation has principally two components – capacity building and the delivery of adaptation measures. The two are inextricably linked, as capacity building will be concerned with creating the environment for effective measures.

The two components have impact at both the national and local levels. At both levels there is a need to strengthen institutions so that they are able to understand and respond to climate change. At the national level, issues to be addressed are integrating adaptation into the planning process, providing reliable information, promoting appropriate technologies and providing social protection schemes. At the local level, the emphasis needs to be on placing communities and civil society at the heart of the adaptation process in terms of planning and implementation.

Although many of the world's poor may not understand climate change, it is clear that they are already adapting in several ways to its effect. In Bangladesh, women farmers are building "floating gardens" – hyacinth rafts on which to grow vegetables in flood-prone areas. In Sri Lanka, farmers are experimenting with rice varieties that can withstand saline intrusion and cope with reduced water. In Nepal, communities in flood-prone areas are

building early warning systems – such as raised watchtowers – and providing labour and material to shore up embankments. Communities in Viet Nam are strengthening age-old systems of dykes and embankments to protect themselves against more powerful sea surges.

In the Mekong Delta, agricultural collectives now levy a tax for coastal protection and are supporting the rehabilitation of mangrove areas. In India's West Bengal, women living in villages in the Ganges Delta are constructing elevated bamboo platforms on which to take refuge above monsoon floodwaters. In neighbouring Bangladesh, donor agencies and NGOs are working with people living on chars – highly flood-prone islands that are cut off during the monsoon – to raise their homes above flood levels by placing them on stilts or higher embankments.[14]

Investment in infrastructure is one means to help communities adapt to a changing climate. One of the key areas will be to also support and develop practical measures to protect and strengthen local infrastructure so that it is able to withstand the effects of climate change.

This brings us to the underlying philosophy of the International Labour Organization's approach to climate change adaptation. It will, of course, be necessary for governments and development agencies to provide a wide spectrum of technical, financial and institutional support to alleviate the problems caused by climate change. However, they equally need to assist communities and institutions with the tools and techniques to deal with the impact of climate change. Investing in local infrastructure can help communities to adapt. At the same time, these investments can be used to generate income and create jobs. These jobs can then be qualified as green jobs.

14 United Nations Development Programme (UNDP): *United Nations human development report* (New York, 2006 and 2007).

Table 1.5: Adaptation to climate change

| | Reactive | Proactive |
|---|---|---|
| Water resources | Protection of groundwater resources<br>Improved management and maintenance of existing water supply systems<br>Protection of water catchment areas<br>Improved water supply<br>Groundwater and rainwater harvesting and desalination | Better use of recycled water<br>Conservation of water catchment areas<br>Improved system of water management<br>Water policy reform, including pricing and irrigation policies<br>Development of flood controls and drought monitoring |
| Agriculture | Erosion control<br>Dam construction for irrigation<br>Changes in fertilizer use and application<br>Introduction of new crops<br>Soil fertility maintenance<br>Changes in planting and harvesting times<br>Switch to different cultivars<br>Educational and outreach programmes on conservation and management of soil and water | Development of tolerant/resistant crops (to drought, salt, insect/pests)<br>Research and development<br>Soil and water management<br>Diversification and intensification of food and plantation crops<br>Policy measures, tax incentives/subsidies, free market<br>Development of early warning systems |
| Forestry | Improvement of management systems, including control of deforestation, reforestation and afforestation<br>Promoting agro-forestry to improve forest goods and services<br>Development/improvement of national forest fire management plans<br>Improvement of carbon storage in forests | Creation of parks/reserves, protected areas and biodiversity corridors<br>Identification/development of species resistant to climate change<br>Better assessment of the vulnerability of ecosystems<br>Monitoring of species<br>Development and maintenance of seed banks<br>Inclusion of socio-economic factors in management policy |
| Coastal protection | Protection of economic infrastructure<br>Public awareness to enhance protection of coastal and marine ecosystems<br>Building sea walls and beach reinforcement<br>Protection and conservation of coral reefs, mangroves, sea grass and littoral vegetation | Integrated coastal zone management<br>Better coastal planning and zoning<br>Development of legislation for coastal protection<br>Research and monitoring of coasts and coastal ecosystems |
| Health | Public health management reform<br>Improved housing and living conditions<br>Improved emergency response | Development of early warning system<br>Better and/or improved disease/vector surveillance and monitoring<br>Improvement of environmental quality<br>Changes in urban and housing design<br>Improved sanitation and drainage |

Source: ADB

## 1.4 The cost of adaptation

The World Bank has produced a preliminary estimate that it will cost around US$10–$40 billion to climate-proof investments in developing countries. The World Bank's calculations primarily account for the costs faced by national governments in integrating adaptation into ongoing planning, policies and practices and climate-proofing ongoing infrastructural investments.

The figures do not account for:

i) the costs for national governments to climate proof the existing stock of natural and physical capital where no new investment had been planned;

ii) the cost of financing new investments needed specifically because of climate change; and

iii) the costs faced by communities for the vast majority of their adaptation needs.

Oxfam estimates that the cost of adapting to climate change in developing countries is likely to be at least US$50 billion annually.[15] This will involve scaling up the most urgent and immediate priorities, scaling up community-level projects, and identifying many of the costs that have not yet been calculated. Kermal Dervis, former head of the United Nations Development Programme, believed that donors need to provide 50 to 100 per cent more financing over and above current aid – equivalent to US$50–$100 billion annually – to cover the impacts of climate change. Likewise, Christian Aid estimates that tackling adaptation will require a global fund of US$100 billion each year.[16]

Some funds are already being made available for climate adaptation programmes by the international community. However, it is clear that there will be a delay while the management and disbursement of the funds is established. Communities cannot afford to wait. Supporting what Oxfam has called an action-learning process needs to be implemented now.[17] This would involve testing, building up organizational capacity and scaling up successful demonstration projects. The ILO already has many of these tools available for communities to use.

15 Oxfam International: *Adapting to climate change*, Oxfam Briefing Paper 104, Oxford, 2007.

16 Christian Aid press release: "Global war chest needed to fight impact of climate change on poor" (6 April 2007).

17 Oxfam International: *Adapting to climate change*, Oxfam Briefing Paper 104, Oxford, 2007.

## 1.5 Climate change and poverty

Nazmul Chowdbury from Practical Action has pointed out that the slogan "making poverty history" is likely to look increasingly unreachable as climate change impacts increase. At the macro level, the global effects of climate change could eventually result in a loss of as much as 10 per cent of GDP.

Economic forecasting is fraught with difficulty, especially in the case of climate change in which there are so many variables. Nevertheless, most experts agree that climate change will indeed result in a 5–10 per cent reduction in global GDP.[18] Developing countries are expected to experience reduction at the higher end of this range. This could mean that future GDP growth may be flattened by climate change.

Climate change is therefore a serious threat to poverty reduction. Developing countries will suffer most because they are, on average, warmer already and have high rainfall variability. Most developing countries are heavily dependent on agriculture which is the most climate-sensitive of all economic sectors. They also have less adequate health provision and low-quality public services. Moreover, their low incomes and vulnerability make adaptation to climate change particularly difficult.[19]

In the developing world, the greatest threat from climate change comes from drought, floods and ever more frequent natural disasters. This will inevitably lead to the greater risk of famine. Coupled with this is the heightened risk of disease. Moreover, to such a dire scenario should be added the risk of social unrest as more and more people sink in to poverty. Even with the current rate of climate change it is difficult to see how the United Nations Millennium Development Goals, which aim to halve world poverty by 2015, can be met.

Poor people suffer most because they do not have access to formal information networks that could make them aware that storms or floods are on the way. They also live on land that is more susceptible to storms or flooding because they cannot afford to live anywhere else. Above all, they depend to a great extent on the land and

18 N. Stern: Stern review: *The economics of climate change* (Cambridge, Cambridge University Press, 2006).

19 Christian Aid: "The climate of poverty: Facts, fears and hope", London, May 2006.

agriculture for their livelihood. As the Red Cross puts it: "The vulnerability of the poor is [presently] intimately tied to development patterns: environmentally unsound practices, population growth, urbanization, social injustice, poverty and short-term economic vision."[20] To this is now being added the effects of climate change.

Because the poor start with these disadvantages, climate change is likely to reduce already-low incomes and increase illness and death rates. Income from farming will fall and increase poverty, forcing them to use up any limited savings that they have.

Health and agricultural incomes are under particular threat from climate change. The value added in agriculture as a percentage of GDP is in inverse proportion to the GDP per capita. In other words, the poorer the country, the greater the dependence on agriculture. In general, rising temperature has an adverse effect on crop yields, thus reducing farm incomes still further for small farmers. The effect of more frequent storms, flooding and salination in coastal areas will exacerbate the problem.

At the national level, the reduced GDP will inevitably mean that government services will be reduced, including poverty-reduction programmes aimed at meeting the 2015 MDG targets.

***Potential impacts of climate change on the MDGs***

*1. Eradicate extreme poverty and hunger*
*Climate change is predicted to:*
- *degrade the forests, fish, pastures and crop land that many poor families depend on for their food and living*
- *damage poor people's homes, water supply and health, which will undermine their ability to earn a living*
- *exacerbate social tensions over resource use, which can lead to conflict, destabilizing livelihoods and forcing communities to migrate.*

*2. Achieve universal primary education*
*Climate change could undermine children's ability to attend school:*
- *More children (especially girls) are likely to be taken out of school to help fetch water, care for ill relatives or help earn an income.*
- *Malnourishment and illness among children could reduce their school attendance and impair their learning when they are in class.*
- *Floods and hurricanes will destroy school buildings and force migration.*

*3. Promote gender equity and empower women*
*Climate change is expected to exacerbate current gender inequalities:*
- *Women tend to depend more on the natural environment for their livelihoods than men do and so are more vulnerable than men are to its variations and change.*
- *Women and girls are typically the ones to fetch water, fodder, firewood and often food. In times of climate stress, they must cope with fewer resources and a greater workload.*

20 Red Cross: *Preparedness for climate change* (2004).

- *Female-headed households with few assets are affected particularly severely by climate-related disasters.*

*4–6. Reduce child mortality, improve maternal health and combat major diseases*
*Climate change will lead to more deaths and illness due to heat-waves, floods, droughts and hurricanes:*
- *It may increase the prevalence of diseases spread by mosquitoes (such as malaria and dengue fever) or of those spread in water (such as cholera and dysentery). Children and pregnant women are particularly vulnerable to these diseases.*
- *It is expected to reduce the quality and quantity of drinking water and exacerbate malnutrition among children, particularly in sub-Saharan Africa.*
- *Reduced spending on health due to reduced household income.*

*7. Ensure environmental sustainability*
- *Climate change will alter the quality and productivity of natural resources and ecosystems, some of which may be irreversibly damaged. These changes will also reduce biological diversity and compound existing environmental degradation.*

*8. Develop a global partnership*
- *Climate change is a global challenge, and responding to it requires global cooperation, especially to enable developing countries to tackle poverty and inequality. It heightens the need for donors to honour their official development assistance commitments and to provide additional resources for adaptation.*

Source: Adapted from Sperling (2003) and Reid and Alam (2005), in Oxfam International: *Adapting to climate change*, Oxfam Briefing Paper 104, Oxford, 2007.

## 1.6 Climate change and local development

The point has been made before that climate change will result in events previously considered as one-off disasters becoming commonplace. This not only requires practical measures to adapt to the new situation, such as improved and strengthened water management, but also in terms of the way that communities and local institutions function.

Whether or not national governments are able to respond effectively to provide support to those most affected by climate change, it is clear that the major onus will fall upon communities. This implies that not only do they need information on the likely consequences of climate change in their area but also that they have the capacity to respond to the changes.

As discussed in section 1.2, agricultural crop yields will be affected by a whole variety of factors caused by climate change. This will result in reduction of income. Farmers need to adapt, for instance, in terms of looking for alternative technologies to increase crop yields by using the means to reduce the risk of crop infestation and by assessing the possibilities of alternative non-agricultural income generation.

Communities need to be aware of the higher risk of diseases, such as dengue fever, malaria and cholera, and take whatever measures are appropriate to reduce these risks.

Another area for communities and institutions is the development of the infrastructure to deal with the effects of climate change. Whether this is strengthening sea defences, improving urban drainage systems or working together to develop irrigation systems, communities need to be empowered to respond to the challenge. At the local level, government institutions need to take a demand-driven approach rather than assuming that their role is to dictate solutions. Participation needs to be real rather than, as it often is, merely political rhetoric.

Perhaps the most significant change that is required is in the area of water management. On the one hand it seems evident that precipitation is going to be significantly higher and, in the dry season, drought longer and more intense. Management of water therefore is a major issue. This is not only in terms of the more effective use of water but also in obtaining consensus within and between communities to avoid social unrest.

As was demonstrated in section 1.4, communities are already taking action to combat the effects of climate change. Sometimes this is with the support of local or international NGOs. At present, however, these efforts tend to be uncoordinated and piecemeal. What is required is that the institutions working at the local level see planning for and interventions to adapt to climate change as part and parcel of their daily business. It is a sine qua non that communities need to be completely integrated into the process of planning for adaptation; and this must include the meaningful participation of women. Indeed, it is their knowledge and innovation that is often crucial in designing effective programmes.

***Albay in action on climate change***

*The province of Albay in the Philippines is highly exposed to various climate risks, such as tropical cyclones and storm surges. This could worsen as a result of climate change. The provincial government has designated climate change adaptation as a governing policy and is implementing a programme entitled Albay in Action on Climate Change. The intention is to mainstream climate change adaptation into local government planning.*

The positive aspect is that the procedures and systems are available for this partnership between communities and the local institutions to flourish. This is particularly true in relation to the development of a local resource-based approach for climate change adaptation through infrastructure improvement, as the following chapters discuss.

## 1.7 Climate change and crisis response

In the past 20 years, crisis response and disaster relief have become a major industry. Many multilateral and bilateral agencies have set up special units to provide disaster risk assessment, assess levels of vulnerability and respond to disasters. The ILO is no exception. But the ILO programme does not just deal with natural disasters. It also responds to post-conflict situations and the fallout from economic and financial downturns. Climate change will result in a progressively more significant series of natural disasters, to such a degree that they will not be known as disasters but as naturally occurring phenomena. We need to plan for coping with that situation now.

A great deal of the useful work that has been done and the experience gained from the crisis management programmes can be of use in planning and implementing adaptation to climate change.

***Preventing loss***

*One recent global study estimates that US$1 invested in pre-disaster risk management activities in developing countries can prevent US$7 in losses.*

To some extent this is already happening as more and more agencies recognize that the climate change "events" are becoming more frequent and numerous. At the global level, most of the discussion focuses on mitigation. However, at the practical level, many NGOs and some international agencies are providing support to adaptation.

What is clear is that a change of mindset is necessary. Natural disasters have resulted in the disaster agencies moving into action and appealing for additional funds to be made available to finance the relief programmes. Thus each natural disaster is treated as a one-off incident. This will no longer be the case. Climate change is making severe floods and drought commonplace. Rather than waiting for them to happen and then responding, we need to plan on the basis that they will happen. Thus major typhoons and cyclones will be the norm in areas such as the coast of Viet Nam and the eastern seaboard of the Philippines. Floods in India should not be considered as catastrophic unique experiences but as what can be expected every year. The impact of climate change needs to be planned for and protected against now.

## 1.8 Potential to create jobs and sustain livelihoods

Already some countries have accepted that a change in mindset is necessary and have taken action to limit the impact of climate change. This is true in the health sector, in agriculture and in infrastructure, the sector upon which this guide focuses.

The work on infrastructure consists of two main components:

i) climate proofing existing infrastructure; and
ii) preparing for future climate change.

"Climate proofing" refers to the need to strengthen the existing infrastructure so that it is more capable of resisting the impact of climate change. Raising and strengthening sea dyke defences, lifting road levels above the predicted increase in flood levels, strengthening water-retaining structures so that the increased water flow can be controlled are all part of climate proofing.

New infrastructure needs to be designed and built in accordance with the new parameters set out by the predicted impact of climate change. Water-management schemes need to take into account the predicted increase and variation in precipitation. The design of irrigation schemes should take into account the major variation in water flow. Small dams and retaining structures should be planned on the basis of major increases in water pressures. Many countries do not have enough water storage to manage current annual demand based on the average seasonal rainfall cycle. This will become an even greater problem in the future with less predictable cycles.

In general, infrastructure investments can provide at least partial protection, enabling countries and people to manage the risks and limit vulnerability.

Currently, the emphasis is on climate proofing. In Cambodia, estimates suggest that US$10 million of investment is required to construct water gates and culverts for newly rehabilitated road networks, which were not designed to cope with the increase of flooding. In Bangladesh, projects worth US$23 million have been identified by the Government to create a coastal buffer zone in regions vulnerable to storm surges, with an additional US$6.5 million to counter the effects of increasing salinity in coastal soils. In Viet Nam, the Government has drawn up a comprehensive strategy for reducing disaster risk in the Mekong Delta.[21]

The Viet Nam example highlights one of the crucial elements of adaptation to climate change. Adaptation planning is unlikely to succeed if it is approached as a stand-alone exercise. In Viet Nam, the Mekong strategy is integrated into the country's national poverty reduction strategy and medium-term expenditure framework, linking it to public policies aimed at overcoming hunger and reducing vulnerability.

There is no doubt that both climate proofing of existing infrastructure and protecting future investments require very significant funding. This is needed not only for the investments themselves but also for developing the institutions responsible for the work. As has been emphasized before, much of the work will be carried out at the local level and depends to a great extent on the use of local resources. A major opportunity therefore arises for employment creation through these programmes. This is particularly welcome, given the number of rural jobs that will be lost in agriculture, as detailed previously.

21 Examples taken from country National Adaptation Programmes of Action.

The ILO has been concerned for some time that future job creation should not result in an addition to the causes of climate change. In collaboration with the United Nations Environment Programme (UNEP), it recently set up an initiative that aims to promote the concept of green jobs.[22] The ILO defines "green jobs" as positions in agriculture, manufacturing, construction, installation and maintenance as well as "work in agriculture, industry, services and administration that contributes to preserving or restoring the quality of the environment".

The ILO's concern is that climate change will have an effect on both the quality of jobs, meaning their content, and the quantity of jobs available. Given the effects predicted and described in this chapter, it seems that there will be job losses. Moreover, those losses will be felt most by the rural poor, who are so dependent on agriculture. Conversely, the required adaptation measures can provide new jobs in the rural areas. Although the original focus was on environmentally sound employment policies, the ILO has recognized that climate change is both a threat and an opportunity for the creation of green jobs. In the infrastructure sector, one of the ways to ensure more environment-friendly job creation is to emphasize the potential of labour-based, employment-generating operations.

The ILO, through its Employment Intensive Investment Programme (EIIP), has many years of experience in the development and implementation of local resource-based infrastructure programmes. These programmes focus on the development of local capacity, both public and private, and the application of efficient labour-based methods in the provision of infrastructure services.

The EIIP programme focuses on four main areas:

- Labour-based works that contribute to environmental preservation and improvement and land conservation and productivity (soil conservation, reforestation, land improvement, irrigation, flood protection, etc.).
- Labour-based works in response to natural disasters, rebuilding community and public infrastructure and improving infrastructure (embankments, dykes) to mitigate the impact of future disasters.
- Employment creation as part of the local resource-based strategy promoted in rural infrastructure works, in which the use of local resources are optimized,

22 Worldwatch Institute: *Green jobs: Towards decent work in a sustainable, low-carbon world* (Nairobi, UNEP/ILO/IOE/ITUC, 2008)

thereby minimizing the use of heavy equipment and applying environment-friendly construction methods.

- Employment creation as part of urban slum development strategies to improve working and living conditions in low-income settlements (water supply, sanitation, solid waste disposal, drainage improvement and flood protection).

The experience the ILO has gained in all four areas provides a solid base for providing support in the development and implementation of local resource-based infrastructure programmes on adaptation to climate change.

## 1.9 Summary

Anyone coming to the details of climate change for the first time is shocked by the dire predictions that are being made for its impact. In reading the literature, it is easy to become depressed, if not resigned, to the massive impact of the change. However, the effect of climate change also provides an opportunity for change and innovation. This is particularly so in the infrastructure sector.

The impacts on employment, income and poverty are likely to be significant but are still poorly understood. Nevertheless, the predictions are that climate change will result in major job losses. These will be unfairly distributed, with the developing world likely to suffer the most. In these countries it will be the poor who are most vulnerable because the majority of them are involved in sectors that are most at risk, particularly agriculture and fisheries.

In the infrastructure sector, and particularly in the massive adaptation measures that need to take place, there is the potential to actually create jobs. Many of these green jobs can be created in the areas in which job losses will be most extreme. Because adaption needs to take place at the local level and much of it in the rural areas, there is the possibility of using local labour to implement the adaptation measures. However, this will only happen if the opportunity is taken to apply a local resource-based approach to the extent that is technically and economically feasible.

It is fortunate that many years of research and practical experience have provided the means to implement local infrastructure works, using local resources in an effective and efficient manner. The major challenge will be to strengthen agencies and institutions so that they have the capacity to implement major, nationwide infrastructure adaptation programmes using the existing technologies.

2

# Public works and green jobs

# Public works and green jobs

## 2.1 The poor will suffer most

All the substantive assessments of climate change reflect the same concern. As we have seen in chapter 1, it will be the poor of the world who will suffer the most. This is particularly cruel as the poor have been the least active in its production. It is thus incumbent upon those with the resources to ensure that the effects are planned for and limited to the greatest extent possible.

Using the conservative estimate of a two-degree rise in the earth's temperature by

2050, the predictions for the poor are still dire:[1]

- Changing weather patterns will seriously affect water supplies. Those particularly affected will be in the Indian subcontinent and parts of China.
- Melting glaciers will increase flood risk during the wet season and strongly reduce dry-season supplies.
- By 2050, as many as 200 million more people may become permanently displaced due to rising sea levels, increased flooding and more intense droughts.
- Rising sea levels alone will result in millions more people subjected to floods each year. There will be serious risks in countries like Bangladesh, Viet Nam and the small island states in the Pacific.
- Declining crop yields are likely to leave hundreds of millions without the ability to produce or purchase sufficient food.
- Ocean acidification, a direct result of rising carbon dioxide levels, will have major effects on marine ecosystems, with possible adverse consequences on fish stocks.
- Climate change will increase worldwide deaths from malnutrition and heat stress. Vector-borne diseases, such as malaria and dengue fever, could become more widespread if effective control measures are not in place. In higher latitudes, cold-related deaths will decrease.

The dire situation facing many developing countries is illustrated by the Philippines. Even before the advent of climate change, life was not simple for the majority of the population that lives in the rural areas and whose livelihoods depend on agriculture and fishing. Life was already a constant struggle for the 30 per cent of the population who live below the poverty line and, like 70 per cent of the population, are dependent on agriculture. As much as one-third of rural households are landless agricultural workers, and even those who farm their own land are tenants or have very small holdings.

**_Changing conditions_**

*Tulsi Khara, India has lived all her 70 years in the world's largest delta, where the Brahmaputra and Ganges rivers meet and flow into the Bay of Bengal.*

*"We are not educated people, but I can sense something grave is happening around us. I couldn't believe my eyes - the land that I had tilled for years, that fed me and my family for generations, has vanished. We have lost our livelihood. All our belongings and cattle were swept away by cyclones. We have moved to Sagar Island and are trying to rebuild our lives from scratch. It wasn't like this when I was young. Storms have become more intense than ever. Displacement and death are everywhere here. The land is shrinking and salty water gets into our fields, making them useless. We feel very insecure now."*

Source: WWF India and Vissa Sundar

Agricultural yields are modest, and although agriculture accounts for 35 per cent of the labour force, it contributes less than 20 per cent of GDP. The level of income of these households dependent on

1 N. Stern: *Stern review: The economics of climate change* (Cambridge, Cambridge University Press, 2006).

agriculture is low. For those who depend on fishing for a livelihood, the situation is even more difficult. These fishermen are among the poorest of the poor, with incomes averaging only 25 per cent of the national average. Their livelihood has been undermined by low production, which is the result of the encroachment of commercial fishermen into shallow waters, destruction of the marine environment, over-fishing and an increasing number of fish ponds.

The coastal ecological system has been seriously undermined because a large proportion of the mangrove forests have been cleared to construct fishponds. Coral reefs have sustained serious damage from illegal fishing and by silting from erosion. Freshwater lakes have been polluted from industrial and agricultural waste.

This is the situation in a middle-income country in the region, even before climate change makes a major impact. That situation is only going to become worse with climate change.

As far as agriculture is concerned, climatic conditions are a major determinant of crop production patterns. For example, coconut trees need a constant supply of water and do not do well in areas with a prolonged dry season. Sugarcane, on the other hand, needs moderate rainfall spread out over a long growing period and a dry season for ripening and harvesting. In the Philippines, for instance, the seasons are now becoming more unpredictable and severe.

In many developing countries, the capacity of poor people to withstand extreme weather events, which may become the norm with the predicted climate change, is constrained by low income levels, by limited access to credit or loans and a general lack of information to permit them to prepare for these events. These constraints are likely to become worse as wet and dry seasons become increasingly difficult to predict.

Poor people are adversely affected by climate change in a variety of ways; and they are affected differently depending on where they live. People living in the drought areas of India suffer different effects to those in the cyclone subjected areas of Viet Nam and the Philippines, for example.

Although there are several predictions of the size of the increase in the earth's temperature, it is generally accepted that

with the level of emissions that have already taken place, a rise of 2°C over the next 20 to 30 years is inevitable. It is also confidently predicted that this will result in an overall reduction of agricultural yields, salination of the soil, more and prolonged flooding in some areas and extended and more severe drought in others. Fishing will be affected because of the damage to coastal areas. Forest products will be affected. Health problems, such as diarrhoea and water-borne diseases, will become more severe. In many areas, the access and availability of water will generally decrease. Taken together, this implies that the livelihoods of poor people is presently and will remain under severe threat. Adaptation has become necessary.

One of the primary areas for intervention is the provision of employment so that the negative effects of climate change can at least be partially compensated by alternative income sources.[2]

## 2.2 Infrastructure and climate change

As previously noted, infrastructure and public works will have a major role in adapting to climate change. In the infrastructure sector, adaptation translates into proofing so that existing physical infrastructure can more effectively withstand the impact of climate change. Adaptation will also be seen in the planning and implementing of new programmes so that they are designed for the predicted impacts. Adaptation is not only concerned with the hard issues of designing structures that can deal with the increased and more variable levels of precipitation and floods. It is also related to the development of institutional structures more in tune with the changed environment in which natural disasters, now considered as one-off events, are commonplace and need to be planned for as such. This also implies major initiatives at all levels to develop awareness of the changes that will take place and provide the capacity to face up to them.

At the national level there will be a need to restructure physical infrastructure planning. Natural disasters are often dealt with by a separate ministry or agency; they typically do not interact in any detailed way with the line ministries dealing with roads, irrigation, forestry, soil conservation or coastal defences. For adaptation measures to be effective, they will need to be better integrated into the work of these ministries or agencies.

2 In Asia, up to 60 per cent of the income of rural households is directly related to agriculture. Climate change will seriously affect employment in the sector especially jobs that are dependent on harvesting and crop processing (see Worldwatch Institute: *Green jobs: Towards decent work in a sustainable, low-carbon world* (Nairobi, UNEP/ILO/IOE/ITUC, 2008).

International bodies are currently supporting national governments to develop measures to both mitigate against and adapt to climate change. A fast-track process for financing their most immediate and urgent adaptation needs was set up under the United Nations Framework Convention on Climate Change (UNFCCC) in 2001. To date, several countries have submitted national adaptation plans of action to the UNFCCC, setting out priority projects together with the budgets required for implementing them.

For infrastructure adaptation measures, however, much of the onus needs to be on local solutions involving communities. To some extent, this is already taking place where communities have been encouraged to take such measures. Poor people who are beginning to feel the effects of climate change are already seeking ways to adapt to it. Nevertheless, localized, spontaneous responses will not be enough. We need major infrastructure programmes. The challenges in developing these programmes will be:

- sourcing the substantial funds that will be required;
- developing the technical, managerial and administrative capacity at all levels to plan and implement such programmes; and
- ensuring systems, procedures and funding are in place for operation and maintenance.

Much has been written about the scale of problems that are and will be associated with climate change. But the emphasis has been on mitigation. Principally, this is concerned with keeping the global temperature rise below 2°C through a series of measures that will require global collaboration. Hopefully, these measures will be successful. However, such a rise, seen by many as inevitable, will have major repercussions that can only be effectively tackled through adaptation measures.

For the infrastructure sector, and in particular rural infrastructure, the dire predictions do not imply a major change of technology or indeed a reassessment of the manner in which projects are implemented. What is clear is that the sector needs significant funding,[3] a massive increase in its capacity and major rural infrastructure programmes focused on climate change adaptation. Climate proofing and adaptation requires an increase in capacity at all levels, from the national to the local. It needs a major increase in the skill levels and organizations that are capable of dealing with the increased work load.

3 See chapter 1, section 1.4.

## 2.3 Main economic and social sectors affected

Climate change is affecting and will continue to impact several sectors. Many organizations and commentators have discussed what the principal issues are in the different sectors in regard to climate change adaptation. Proposals have been made in relation to policy, research, finance, institutional change and awareness raising. Relatively little, however, has been suggested as to how the infrastructure sector can respond to the challenges. This is somewhat surprising, given that it is clear that this sector will need to be at the forefront of efforts to adapt to climate change. If we look at the five sectors discussed in chapter 1 and pick out the activities that are the concern of the infrastructure sector, we arrive at the list presented in table 2.1.

Table 2.1: Infrastructure-related measures to adapt to climate change

| | |
|---|---|
| Agriculture | Erosion control<br>Dam construction for irrigation<br>Educational and outreach programmes on conservation and management of soil and water<br>Agricultural road embankments<br>Soil and water management |
| Water management | Protection of groundwater resources<br>Improved management and maintenance of existing water supply systems<br>Protection of water catchment areas<br>Improved water supply<br>Groundwater and rainwater harvesting and desalination<br>Better use of recycled water<br>Improved systems of water management<br>Water policy reform, including pricing and irrigation policies<br>Development of flood controls and drought monitoring |
| Coastal defences | Protection of economic infrastructure<br>Public awareness to enhance protection of coastal and marine ecosystems<br>Building sea walls and beach reinforcement<br>Protection and conservation of coral reefs, mangroves, sea grass and littoral vegetation<br>Integrated coastal zone management<br>Better coastal planning and zoning<br>Development of legislation for coastal protection<br>Research and monitoring of coasts and coastal ecosystems |
| Forestry | Improvement of management systems, including control of deforestation, reforestation and afforestation |
| Health | Changes in urban and housing design<br>Improved sanitation and drainage |

Source: ADB

## 2.4 Interventions for adaptation

### Water management and soil conservation

Water is fundamental to our life and well-being. Globally, around 70 per cent of the freshwater supply is used for irrigation and food production. With climate change, droughts and floods are becoming more intense. Rural people try to use the excess

supply of water in the wet season to counteract the lack of water in the dry season by some form of storage. As climate change impacts increase, this balance will be more difficult to maintain for a variety of reasons. For one, the rise in temperature is predicted to impose more prolonged and more severe dry periods in areas that are already relatively dry, thus water availability will decrease. Conversely, areas that have intense wet seasons, such as South-East and South Asia, will have heavier and more prolonged rainfall.

For some of the countries of the Asia region, the overriding problems will be the increase in water availability. This would normally be a good thing. However, it will be the timing of the increased precipitation that causes the problem. Most of this will come during the wet season. This has serious effects not only in terms of flooding but also in relation to water management, water storage and the conservation of water catchment areas. Investments in these areas are highly necessary.

## Irrigation

Agriculture is one of the most climate-sensitive sectors and is being particularly badly hit by the multifaceted impact of climate change. It is confidently predicted that climate change will lead to declines in yields of the world's most important food crops. For example, a recent study suggests that the increase in dry season temperature will result in a massive decrease in the amount of India's most favourable wheat-growing land.[4] The IPCC suggests that in general there will be a general decline in the yields of maize and low-latitude wheat and rice. This will have an effect on the health and

4 R. Ortiz et al.: 2008. "Climate change: Can wheat beat the heat?",in *Agriculture, Ecosystems and Environment* (2008), p. 126.

livelihoods of the mass of subsistence farmers in the developing world. There is a need for these farmers to find alternative sources of income to pay for the food that they are no longer able to produce for their families.

Changes in the length and severity of the seasons will require a change in cropping patterns, water management and a need to diversify into other crops. From the point of view of physical infrastructure, the key issue is water management and, in particular, strengthened and more efficient irrigation systems and erosion control to contend with the increased risk of flooding and prolonged and more severe wet seasons. There is an urgent need for providing small farmers with support in relation to conservation and management of soil and water.

## Forestry

Deforestation is a major source of global gas emissions, accounting for between 18 and 25 per cent of the annual total. In relation to mitigation, checking the rate of deforestation is crucially important. In addition, deforestation produces major environmental problems that can only be exacerbated with the predicted climate change impact. Already, there are major disasters every year caused by excessive runoff due to deforestation. The most dramatic of these are caused by mudslides, which can wipe out entire villages in their path.

Increased runoff carries soil and debris into surface water, reducing water quality for drinking, fisheries and aquatic habitat. If uncontrolled, excess runoff leads to navigable waterways and dams becoming silted up and increases flooding.

Turbidity[5] reduces the effectiveness of chlorination, increases absorption of toxic materials, provides food for microbes that can then multiply in the water-distribution system and interferes with ion exchange and carbon-adsorption processes. It also

5 Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye.

damages irrigation systems and equipment; it forms a film on plant leaves, reducing growth and market value; and it creates crusts on soil surfaces that inhibit water absorption, young plant growth and soil aeration.

In general, the removal of the trees, ground cover and leaf litter allows uncontrolled runoff and nutrient leaching during rains, making reforestation and farming difficult. Siltation caused by excessive runoff kills fish, spawning areas and vegetation needed by fish to reproduce and survive.

It is vital that all climate adaptation programmes contain a reforestation component.

## Flood control

More frequent and more intense cyclones and typhoons and heavier and more concentrated precipitation during the wet seasons are already causing major floods around the world. Drainage systems and water management systems in most countries have not been designed to deal with the levels of intensity that are now becoming common.

The heavier levels of precipitation are a problem in their own right. Coupled with deforestation and inadequate water management, they trigger flooding on an unprecedented scale.

Floods have an immediate effect in terms of the loss of life, the destruction of crops and infrastructure and the health problems caused by contaminated water. They also have a major effect on the economy of the areas suffering from flooding.

Flood control has to be seen in the overall context of water resource management, forestation and soil erosion. Measures are needed to improve the drainage systems, strengthen coastal defences, ensure controlled runoff from road works and lift dykes and bunds to deal with the higher levels of precipitation.

## Rural transport

A well-functioning rural road network is critical for increasing agricultural productivity and production and local development in general. Poverty and isolation are linked, and it is generally accepted that as many people as possible should have at least the possibility of using a motor vehicle in case of emergency. Rural road development offers an effective strategy for targeting poverty directly through road and track investment and improved access to goods, locations and services and indirectly through the better performance of the local economy in the long run. The sustainability of the rural road network is now at risk in areas already affected by climate change.

Various countries will face increased occurrence of flooding during the wet season due to the changing climate. Rural roads will be affected, and new considerations are required for road design. Climate change considerations for rural and agricultural roads will include the raising of embankments to reduce the risk of flooding, the greening and stabilizing of vulnerable embankments and the adapting of subgrade material to withstand higher moisture content. Roads will also require additional structures, such as culverts, bridges and drains

Climate proofing roads through the raising of embankments and the building of more structures, such as bridges, drains and culverts, will be an important element in a strategy to reduce isolation and protect the transport network in areas affected by climate change.

### An integrated and interconnected system

The conventional wisdom until recently was that the dominant drivers of the upward trend in flood damage are socio-economic factors, such as increased population and wealth in vulnerable areas, and land-use change. However, it is now recognized that disaster losses have grown much more rapidly than population or economic growth, already suggesting a negative impact of climate change.

Very few countries have the experience of sustained levels of flooding on an annual basis. Bangladesh is one of them. In general, those involved in water resource

management have dealt with major disasters caused by excessive precipitation as unique events. Climate change implies that they will have to accept that these events are not abnormal weather patterns but what can be expected on a continual basis. In general, this does not mean that the techniques to combat such events need to change but that the attitude to water resource management has to adapt to the sustained severity of the rainfall patterns.

This means improvements in all aspects of the management of water resources. The idea of integrated water resource management (IWRM) has already been proposed as being of critical importance in dealing with the scale of the problem. When responsibility for drinking water rests with one agency, for irrigation water with another and for the environment with yet another, the lack of cross-sector links leads to uncoordinated water resource development and management. This results in conflict, waste and unsustainable systems. Integrated water resources management is a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives. It is different from the sector approach applied in many countries.

IWRM should be an instrument to explore adaptation measures to climate change, but so far it is in its infancy. Successful IWRM strategies include, among others: capturing society's views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, coordinating the use of surface water and groundwater and protecting and restoring natural systems. The level of sophistication and coordination required for IWRM is an impediment to its adoption in many countries. However, the general principles of IWRM need to be pursued. This requires major institutional and strategic decisions to be taken. At the level of implementation, it implies that the management of water resources needs to involve not only the technicians but also those most affected by climate change, which is the rural population.

Adaptation thus does not only have implications for the affected infrastructure. It also requires that the management, planning and capacity of all involved agencies need to be strengthened. Adaptation requires technical designs and the people who can use them in situations with changing site conditions. Infrastructure works need technical planning and proper organization and technical supervision. Master plans for land use and water resource management should ideally be prepared before community schemes are implemented. Adequate funding needs to be made available in relation to the defined needs. Programme formulation and planning, based on a comprehensive and detailed needs analysis, is required before funding is granted.

In addition to better management of the sector, major programmes of both information dissemination and training to all those involved are required. This includes government agencies at all levels, technicians, the stakeholders (those most affected by the impact of climate change), special interest groups (such as environmentalists) and the private sector.

Although water management is particularly important, the same logic has to be applied in soil conservation, irrigation, flood control, rural transport and forestry.

### Institutional constraints

It has been difficult so far to mainstream climate adaptation within development activities. Promoting climate change adaptation has been a problem at the national level because the expertise is still mostly the domain of environmental departments in government and donor agencies. These experts typically have limited influence on government priorities. Consequently, climate remains a secondary concern. In addition, promoting climate change adaptation becomes a formidable task when there is a lack of hard data and it is essentially related to probable future events. In addition, the funding for climate change adaptation needs to be found from an overall budget that is already suffering from the recent economic recession.[6]

Climate adaptation activities also have to deal with the division between the agencies that provide humanitarian assistance and those that are more concerned with a longer-term development agenda. These are often different institutions and have different funding mechanisms, thus making a common approach almost unattainable.

## 2.5 Response

The previous sections lead to the conclusion that there is a need for major programmes focused on climate change adaptation of infrastructure. Such programmes would be primarily concerned with rural infrastructure but would also include local urban upgrading schemes. Moreover, they would be implemented at the local level and rely on local resource-based approaches. The main objective would be to implement infrastructure schemes to help communities adapt to climate changes.

These programmes would not be simple cash-for-work or emergency public works programmes. They would be part of a long-term government programme intended to provide sustainable physical infrastructure assets that would limit, to the greatest extent possible, the predicted impact of climate change.

The emphasis on local resource-based approaches implies that employment and income is provided to those most vulnerable to climate change – the rural poor. However, these programmes are also strategically logical and sensible. Such an approach would ensure that the works that are locally planned respond to actual, rather than perceived, demand; that through the involvement of local communities, contractors and skilled workers, ownership is developed among them, thus providing a greater chance of sustainability; and that funds can be used in a transparent and effective manner.

6 The recent economic recession resulted in large stimulus packages, making available more resources for infrastructure development which offers an opportunity to support adaptation.

Such rural infrastructure adaptation programmes would have four components:

1. Works dealing entirely with climate change adaptation.
2. Climate proofing of existing infrastructure.
3. Ensuring that new infrastructure is also adapted to the effects of climate change.
4. Capacity building and institutional development.

The most significant part of these programmes would focus uniquely on developing rural infrastructure that is specifically adapted to climate change. In addition, they would adapt existing infrastructure to withstand the effects of climate change; for example, improving and strengthening irrigation schemes and drainage channels, building up sea defences and enlarging water retention structures. And they would be geared towards ensuring that other new infrastructure, developed as part of conventional infrastructure programmes, such as roads, is also adapted for climate change.

The public works programmes would require substantial funding, but the benefits would be significant. For instance, a programme of public works for climate change adaptation could, potentially, significantly reduce the effect on the economy in general.

**Communities taking charge**

*Community-driven development helps Philippines town to reduce the impact of floods.*

*For the municipality of Balangiga in Eastern Samar Province, storms and monsoon rains bring floods, sickness and a halt to business activities every time floodwaters rise. Year by year the situation worsens. Things started to improve when residents began constructing a network of canals to channel floodwaters towards the sea. KALAHI-CIDSS is a community-driven development (CDD) programme funded by the World Bank and implemented by the Philippine Department of Social Welfare and Development. It trains villagers in project planning, technical design, and financial management and procurement. The programme also provides villagers with opportunities for accessing information, expressing their opinions, and influencing local governance.*

*The projects not only empowered communities to address flooding and improve their health status, but they also created jobs for residents, thus lessening the level of poverty. But the real gain lies in the communities' as well as the local governments' improved capability in governance.*

Source: World Bank

Programmes of this magnitude will also require a major capacity-building effort at all levels but particularly at the local level. Fortunately, the technology for local resource-based programmes is well understood and has been effectively implemented in several countries. Still, taking the approach to the magnitude of suggested programming will require managerial and technical skills being developed to cope with that scale. It will also be necessary to develop a set of systems, procedures and tools tailored to the demands of such programmes. A good example of how this can be achieved is the rural employment guarantee scheme in India.

Institutionally, such programmes go beyond the mandate of one single ministry. The coordination of the work of several ministries that will be responsible for different aspects of the public works programmes requires both careful and sensitive institutional arrangements. Coordination at the local level is conditioned by the level of decentralization of government responsibilities.

The challenges in developing such programmes are:

- sourcing the substantial funds required;
- developing the technical, managerial and administrative capacity at all levels to plan and implement such programmes; and
- ensuring systems, procedures and funding are in place for operation and maintenance

## Funding

Funding for adaptation should come from the annual budgeted programmes and not special funds separate from the mainstream budget of the involved agencies. This is true whether the funds are budgeted at the national or local level, given that every year the need for adaptation becomes more and more evident.

A rough calculation based on the figures currently predicted for the cost of climate change adaptation suggests that annually this would represent some 1–2 per cent of GDP for most developing countries. This is a very significant figure. However, when compared to the cost of the impact of climate change, predicted to be some 5–10 per cent of GDP, it seems like a worthwhile investment.

Because most of the money for infrastructure climate change adaptation programmes would be additional to existing national budgets, it will require significant readjustment of national budget priorities, augmented by major financial support from the donor community.

An advantage of such programmes would be that they promote employment and income in rural areas, thus providing an economic stimulus to the areas that will be most affected by climate change. They would, in a sense, be a sustained form of social safety net, with the very clear objective of limiting the damage caused by climate change.

The NAPAs are a first step in attempting to define such programmes. A review[7] of some of the action plans, however, suggests that while they have excellent analytical work, they are limited by inadequate financing, the underestimation of adaptation costs and poor links to human development and they have a project-based bias.

## Capacity building

The key to the effective implementing of such programmes will be the capacity of both the public and private sectors. Experience from both emergency public works programmes and labour-based infrastructure programmes provides important lessons here.

Many of the emergency programmes are designed to provide support to areas that have been struck by natural or human-induced disasters. Their primary objective is to supply employment and income. The development of sustainable assets is often seen as a useful but not obligatory secondary objective. Overheads are kept low through the provision of low levels of design, supervision and technical input.

Labour-based infrastructure programmes have the dual objective of providing sustainable infrastructure assets while at the same time relying on local resources, thus developing employment, income and skills. These programmes require similar levels of technical, managerial and administrative inputs as more conventional infrastructure programmes. Overheads therefore are correspondingly higher than for programmes that are substantially concerned with relieving livelihood problems.

Infrastructure adaptation programmes are principally concerned with providing sustainable assets in the face of climate change impact. Consequently, they should be designed as labour-based infrastructure programmes and not as relief programmes.

This being the case, infrastructure adaptation programmes will require major capacity-building efforts to ensure that there are sufficient skills at all levels and in both the public and private sectors. This will, of course, require a relatively high overhead cost. We are fortunate that the training material for such capacity building already exists – a result of the labour-based infrastructure programmes that have been implemented over the past 20 years by the ILO and many others.

7 United Nations Development Programme (UNDP): *United Nations human development report 2007–2008* (New York, 2008).

## Operation and maintenance

Another additional cost not included in cash-for-work or emergency programmes is the operation and maintenance of the infrastructure developed. Although this is usually a small percentage of the cost of the original infrastructure, it is vital if the asset is to be preserved. In addition, maintenance of infrastructure provides the potential for long-term employment because it must be carried out as long as the infrastructure is used.

The problem with the operation and maintenance cost is that it is often not budgeted by those responsible for the upkeep of the facility. Even if it is, the funds are often diverted to what are considered to be more important activities. This is partly because of the structure of government budgets, in which construction or rehabilitation of infrastructure is classified under the development/capital budget while operation and maintenance is designated as a recurrent cost, which can be more easily diverted.

It is thus crucial that in infrastructure adaptation programmes budgets for operation and maintenance are used for their designated purpose. Implementing a maintenance element is not a complicated process, but it is does require that budgets are defined and plans are developed. Consequently, procedures for this need to be put in place.

Whether maintenance is carried out or not ultimately depends on the agency or unit that is responsible for implementation. In general, maintenance is not seen as very important by many involved in infrastructure provision. It is even more important that the infrastructure developed specifically to adapt to climate change is maintained. Not maintaining a road will lead to higher operating costs and possible loss of access. Not maintaining climate change-adapted infrastructure will result in loss of livelihoods at best and loss of life at worst.

At the local level, several innovated procedures have been developed to implement maintenance. Community contracting, contracting individuals or groups, using local contractors and forming user groups have been effectively used in several countries.

Maintenance needs to be established in any climate change adaptation programmes from the beginning. This means funding needs to be set aside for it, implementing systems and procedures need to be in place and effective and applied monitoring systems need to be set up to ensure compliance.

## 2.6 Examples of adaptation at the community level

Throughout history, communities have attempted to protect themselves against the vagaries of climate by building infrastructure. Flood defences and drainage systems, reservoirs, wells and irrigation channels are all examples. No infrastructure, however, provides immunity from climatic forces. What infrastructural investments can do is to provide partial protection, enabling countries and people to manage the risks and limit vulnerability.

In Nepal, the Government handed responsibility for management and use of forests to communities. Almost 33 per cent of Nepal's population are members of a community forest users group, who harvest a range of products for their use and sale. A programme funded by the UK Department for International Development is helping 527,000 households – 11 per cent of Nepal's population – to make a living from the forests. More than 90 per cent of villagers report that their forests are

in better condition now than they were 20 years ago, that wildlife is returning and that water sources are more reliable. These forests also store about 70,000 tonnes of carbon a year. Average household income has increased by 60 per cent over the past five years, partially due to this initiative.

Coastal mangrove plantation or conservation is a highly effective form of coastal protection. In Viet Nam, restored mangroves in Thai Binh Province reduced a 4–metre storm surge in 2005 to a half-metre wave, causing no harm in the area. Similar programmes have been undertaken in Thailand and Indonesia.

### *Managing water*

*In Viet Nam, the Red Cross has worked with local communities to plant 22,000 hectares of mangroves, providing 100 kilometers of protection for sea and river dykes. In India, Oxfam's local partners piloted a scheme to raise the foundations of 600 flood-prone mud houses.*

*In Bangladesh, CARE (funded by the Canadian International Development Agency) worked with local NGOs to support communities in adopting more flood-resilient livelihood strategies, stockpiling food in flood-proof storage, harvesting rainwater and creating floating vegetable gardens in waterlogged areas.*

In the Philippines, the Government developed the Small Water Impounding Project, aimed at reducing flood damage, making more effective use of water resources and generating electricity. The project consists of water harvesting and storage structures, with earth embankment spillways, outlet works and canal facilities. It is designed for soil and water conservation and flood control by holding as much water as possible during the rainy season. The reservoir, with its stored water, serves as an important supplementary source of water for irrigation, inland fisheries and recreational purposes. The watershed is developed for land use that enhances water infiltration and minimizes soil erosion. The farmer beneficiaries of the irrigation water and those of the watershed organized themselves into an association that maintains the system and protects the watershed by their use of sustainable agriculture methods.

In Cambodia, communities in Battambang Province worked with the ILO to raise the road embankment of a community access road. The poor condition of the road during the rainy season prevented road access. As a result, farmers could not transport their produce out of the community, children failed to attend school and access to medical services was constrained. Raising the embankment and keeping the road safe during the wet season immediately resulted in a visible increase in transport and trade.

## 2.7 ILO, public works and green jobs

With its many years of experience of applying local resource-based and labour-based solutions to the development of infrastructure, the ILO is in a privileged position to assist communities in adapting to climate change. The ILO, through its Employment Intensive Investment Programme (EIIP), provides support on a range of issues implicit in the development of rural and urban infrastructure, including:

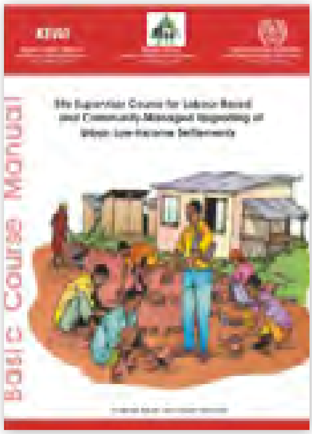
- applying needs-based participatory approaches with communities;
- skills development for local government staff;
- developing appropriate management procedures;
- defining and setting technical and quality standards for rural infrastructure works;
- building effective local organizations for the management of programmes;
- supporting local small and medium-sized contractors;
- establishing local planning and programming procedures that enable communities and districts to ensure that their priorities are addressed by central government;
- developing maintenance systems; and
- providing a set of labour practices in line with the ILO's Decent Work Agenda.[8]

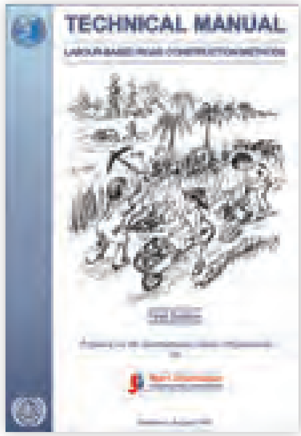
In addition, there is now a need for:

- raising awareness on the effects on local infrastructure of climate change;
- techniques to strengthen existing infrastructure;
- procedures and approaches to plan and design for the expected changes in precipitation and enhanced seasonal climate variations; and
- participatory approaches for more effective land and water resource management.

Over the past 30 years, the ILO has developed a range of expertise and experience in infrastructure development. Perhaps best known for its work on rural road works technology, it also has a significant record of work on building irrigation structures (projects in Cambodia, India, Nepal and Tanzania), providing flood control (manuals and guidelines based on ILO project experience), developing community-based infrastructure (projects in the Cambodia, Nepal, Philippines, Tanzania, Uganda and Zambia) and various manuals and guidelines.

8 D. Tajgman and J. de Veen: *Employment intensive infrastructure programmes: Labour policies and practices* (Geneva, ILO, 1998).






The ILO experience could be invaluable in implementing programmes for climate adaptation. It is also true for works required for climate proofing of existing infrastructure or ensuring that new infrastructure projects are adapted to the exigencies of future climate change.

The ILO has promoted the use of local resource-based technology for two distinct types of programmes: i) for emergency situations to provide income and employment to people suffering the effects of major natural or human-induced disasters, such as the Asian tsunami, or more generally as part of employment-intensive works programmes that have been used to combat rampant unemployment or to provide a kick-start to economies suffering from a recession; or ii) as a rational alternative to equipment, wherever it is technologically and economically competitive. Both applications are needed in dealing with climate change.

Because the poor will suffer most from climate change, it is imperative to alleviate the impact wherever the potential for it exists. For example, because local resource-based methods provide both employment and income, they should be used as the technology of choice for infrastructure development. With climate change, we are not discussing the benefit of moving from equipment-based technology to local resource-based technology. The issue here is that local resource-based methods provide a solution to the loss of income and employment caused by climate change. Their use becomes a social imperative in addition to a technological choice.

Although many people in the

rural areas of developing countries are aware that there have been changes in the climate, few perhaps realize that these changes are permanent and will get worse over time. National governments are developing programmes to educate their citizens about the predicted changes and impacts.

> ***Public works in Nepal***
>
> *The ILO's Public Works Programme was a pioneer in devising an implementation methodology compatible with the participatory and labour-based resources, i.e. labour, skills, cash and materials. Construction works were broken down into packages (piecework), which were executed by members of the users group or by small, unlicensed contractors from the community who had some experience in small-scale construction.*
>
> *During construction, training was given to the works organizers in measuring earthworks, building simple masonry structures, weaving, packing and placement of gabion boxes and other semi-skilled works. Only complex structures were tendered and executed by more skilled, licensed contractors from outside. The ILO approach gave preference to licensed contractors registered at the local district level for the execution of works which were beyond the capacity of the farmers and community-based construction groups. These groups employed local labourers, were available on a long-term basis for follow-up after completion of construction and were more familiar with local conditions.*
>
> *The objectives of this construction methodology were:*
> - *create employment within the local community*
> - *upgrade the building skills of labourers, artisans and local contractors/works organizers*
> - *facilitate post-construction maintenance of rural infrastructure.*
>
> Source: ILO

In most countries, adaptation is not treated as an integral part of national programmes, even in areas heavily impacted by climate change, such as health and agriculture. Instead, a significant proportion of government and donor funds are directed at activities that attempt to mitigate the effects of climate change, with little or no attention paid to the impact of climate change – even in climate-sensitive sectors.

As previously argued, climate change adaptation needs to be tackled as a long-term measure and not as a crisis response. This implies that programmes for infrastructure need to be budgeted and implemented as mainstream activities, both at the national and more importantly at the local levels. Both employment-intensive public works schemes and the use of labour-based methods as the technology of choice need to be part of these programmes. This would help empower communities to marshal available resources and participate in the necessary climate change adaptation measures.

In relation to infrastructure and climate-proofing programmes, the same techniques that the ILO has used previously would be applied. However, it would require a thorough understanding of the change in climate that will take place. For example, irrigation channels would need to be improved to deal with much higher rates of flow. The design characteristics of existing water-retaining structures would be assessed to ensure that they are sufficient in the future. Coastal defence works would be improved to deal with the expected rise in sea levels and the expected increase in typhoons and El Niño effects. The ILO's expertise in local-level planning, community organization, capacity building and skills development would all be necessary.

Although implementing these works will be largely at the local level, they should not be carried out as isolated, externally funded technical projects. They have to be part of an overall national effort. This will require major effort in terms of national coordination and mainstreaming disaster-relief programmes into the overall programme of climate proofing and adaptation. Based on its extensive experience, the ILO can assist national governments in the planning and design of such programmes, and with the capacity building required, particularly at the local level.

Local governments often lack the capacity to provide adequate services to poor settlements. One of the cornerstones of the ILO programme has been the development of local government capacity.[9] Adaptation to climate change has become an element of the ILO's work and will be an area of increasing concentration. For instance, the ILO already assists in developing the capacity of local government staff to be aware of the expected impact of climate change and to plan, design and implement rural infrastructure programmes accordingly.

Being closer to the problems caused by climate change, communities are aware and can provide solutions. However, they typically lack organization, information, technical skills, management capacity, funding and contacts. The ILO has been involved with community-based programmes of

9 See for example G. Edmonds and B. Johannessen: *Building local government capacity for rural infrastructure works* (Bangkok, ILO, 2003).

infrastructure development for several years.[10] It has learned from this experience, particularly in relation to the development of local-level planning procedures based on the actual rather than perceived needs of people and the use of community-based contracts for implementing work.[11]

Substantial parts of the work can be implemented through some form of community-based agreement or contract over which communities have control. This form of interaction will require that both communities and local government agencies receive adequate capacity building. The ILO can provide relevant knowledge and expertise.

The ILO has worked closely with the United Nations Environmental Programme, UN-HABITAT and the United Nations Capital Development Fund on community-based programmes and would expect to continue that close collaboration.

**Irrigation in Nepal**

The aim of the ILO-supported Dhaulagiri Irrigation Development Programme in Nepal was to secure sufficient and reliable irrigation water to small-scale farmers in the mountainous areas to increase food production and thereby contribute to the alleviation of poverty.

While irrigation remained the primary intervention, additional activities such as agricultural extension, income generation, environmental protection, community forestry and mini hydropower were implemented. The implementing strategy was a demand-driven, employment-intensive participatory approach. To sustain the irrigation infrastructure, participation was perceived not merely as involving farmers in the construction and rehabilitation of irrigation schemes but principally as a means to develop institutional, financial and administrative community-based units. These were designed so that the community could operate and maintain an irrigation scheme. Farmers and committee members received training to develop and improve their skills.

The programme also worked with local NGOs that engaged in community organizing by training staff in income-generating activities and environmental protection. With the changes, sufficient irrigation water has increased food production in the programme area by some 20–30 per cent, either due to increased yields or to the new practice of multi-cropping.

Source: ILO

## Employment creation and green jobs

Infrastructure programmes aimed at both climate proofing and adaptation are already being conducted, although on a limited scale. However, as previously noted, governments need to make major investments if the impact of climate change is to be reduced. One of the positive elements of these investments could, and should, be the potential for creating employment for those who will be affected the worst by climate change. The ILO's decades of experience with employment and income generating in the infrastructure sector will be valuable in helping governments address that needed employment creation.

10 Community-based works have often been misconstrued to mean those works that the government cannot afford to do and are therefore left to communities to deal with. Rural road maintenance is a good example of this. Climate change adaptation will certainly cost a great deal of money but it would be adding insult to injury if rural communities were left unsupported to adapt their infrastructure to deal with a phenomenon for which they are in no way responsible.

11 See J. Tournée and W. van Esch: 2001. *Community contracts in urban infrastructure works – Practical lessons from experience* (ILO, 2001) and P. Oakley: *Organisation, contracting and negotiation in development programmes and projects: A study of current practice at the community level* (ILO, 1999).

## 2.8 Examples of ILO work in adaptation programmes

The sectors in which infrastructure development can help tremendously in climate change adaptation and generate employment are summarized in table 2.1. In practice, the key areas are irrigation, soil and water conservation, flood control, rural transport and forestry.

### Irrigation

Many poor farmers lack any irrigation facilities and mainly rely on the rains. With more severe weather, proper water resource management becomes more important. Equally, due to higher frequency of floods, it is important that appropriate measures are installed to deal with such eventualities. Dealing with increased flows in irrigated areas and providing effective drainage often involves substantial civil works. The ILO has shown that such works can be carried out effectively by communities, using local labour, skills and materials.

The ILO programmes in Nepal and Cambodia also demonstrated an instrumental element in the ILO approach. They focused on the active involvement of the targeted beneficiaries in the identifying, prioritizing, selecting, implementing and managing of community-based interventions.

## Soil and water conservation

Soil and water conservation include the prevention and reduction of soil erosion, compaction and salinity, the maintenance or improvement of soil fertility and the conservation or drainage of water.

Soil and water conservation are generally interrelated, in that methods that control and conserve water often also conserve the soil and control erosion. In arid and semi-arid regions, the focus of soil and water conservation will be on retaining rainfall, reducing storm-water runoff, improving infiltration and increasing the water storage capacity of the soil. In humid and sub-humid areas, a balance needs to be found between conserving soil and water on one hand and the avoidance of surface water-logging and erosion on the other.

Successful soil and water conservation programmes can be achieved only when farmers are actively involved in the planning and implementing processes. Ideally, participatory planning should be approached at the hydrological catchment level rather than with individual farmers or an administrative district.[12]

The ILO work on soil conservation has formed part of its overall programme on rural road works and small-scale irrigation and has concentrated on protecting new infrastructure and addressing soil erosion, which results in landslides and deforestation.

## Flood control

Due to global warming, sea levels are expected to rise at a rate between 0.3 and 1 metre over the next 100 years. This situation requires a significant upgrading of protective measures and will not only be limited to a narrow coastal zone. River beds will rise and this, along with other backwater effects, will have much larger influence in the riverine area than near the sea.

What seems most likely is that climate change will increase the variability of already highly variable rainfall patterns, requiring greater investments in managing both drought and floods. Because of the large variability in river flows across seasons and

12 ILO: *Training element and technical guide on small earth dams, dam construction and soil conservation* (ILO Special Public Works Programme, 1998).

years, flood control works and artificial storage are important elements of river basin systems. In past decades, many river basins have experienced extreme flood events. This has reinforced the need for technical flood control measures to be combined with effective water retention and water discharge retardation and with other non-structural measures, like flood forecasting and evacuation.

Flood control is seen as part of the ILO work on mitigating the impact of future natural disasters and climate change. The construction, rehabilitation and repair/maintenance of earthen flood control structures, such as dykes, embankments and levees, offers substantial scope for the application of labour-intensive and labour-based approaches.

Projects in which the ILO has been involved in Bangladesh and Viet Nam have demonstrated that the strengthening of sea defences through the improvement of dykes and the provision and improvement of small dams can create employment. In general, these types of projects lend themselves to the use of labour-based methods. In addition, the experience in Viet Nam shows that simple community contacts, such as those promoted by the EIIP, can be used effectively in flood control work.

## Rural transport

As with most other infrastructure, the road network is highly sensitive to excessive rains and floods. However, roads often restrict the natural flow of water and, as a result, can cause additional damage if the designs are not right. If carefully designed, road components such as embankments, river crossings and cross-drainage can function as integral parts of the water management system in a given area. Equally, roads along rivers and coastlines can act as effective barriers against spring tides and floods.

Good-quality roads are essential for communities to maintain their daily lives and economic activities, but particularly during bad weather, such as in rainy seasons. Children need to go to school, families need continued access to medical facilities and the local economy needs continued access to markets. The roads provide access to where people may need assistance and allows for evacuation of disaster areas.

What are the criteria for a good-quality road? The most basic feature is to ensure that the road is open throughout the year, providing all-weather access. In this respect, the number-one design criteria relate to its resilience to water and expected weather conditions. To achieve this, the road network needs to be designed to deal with expected intensities of rain and floods. River crossings and drainage systems must be designed with sufficient capacity to deal with the worst case scenario. If not, the roads will fail, isolating communities.

More frequent storms and floods will certainly have an impact on the road network. Both the construction and maintenance of roads will be more costly because they will need to deal with more intense and frequent flows of water resulting from the more demanding weather. To date, drainage structures and water management for road design purposes have been based on the weather patterns of the past 30 years. Roads now need to cater for more severe weather than in the past, which poses new challenges to design, construction and maintenance. In many areas, floods are now more severe than in the past. This implies that roads need to be designed with higher embankments and larger and more frequent cross-drainage structures. In addition, higher and more intense rainfall will demand higher maintenance costs.

Although climate change poses new challenges to the road sector, these can all be addressed by relying on existing technology and work methods. Experience from past and ongoing work clearly demonstrates that rural road construction and maintenance can be carried out effectively by relying on the local resource-based approach. This

approach also can be used to prepare access roads in rural areas to deal with more severe weather patterns.

## Forestry

Forests are one of the most important natural resources for rural people in developing countries. Forests supply wood, fibre, fuel wood and non-wood forest products. Planted forests, if managed in a sound manner, can contribute positively towards soil and water protection, the rehabilitation of degraded lands and the restoration of landscapes.

Stopping or slowing deforestation and forest degradation (loss of carbon density) along with the sustainable management of forests may significantly contribute to avoiding carbon emissions, conserve water resources, prevent flooding, reduce runoff, control erosion, reduce siltation of rivers and protect fisheries and investments in hydro-electric power facilities. At the same time, it can preserve biodiversity. Preserving forests also conserves water resources and prevents flooding. By reducing runoff, forests also control erosion and salinity. Maintaining forest cover can thus reduce the silting of rivers and protect fisheries and investments in hydro-electric power facilities.

The current trends of deforestation are, to a large extent, the result of land use change, in particular due to the expansion of agricultural land and agro-industrial development. This, in turn, is closely connected to the conditions of rural livelihoods, the increasing demands for food, feed and fibre and overall economic development. Addressing deforestation and forest degradation therefore needs to be viewed beyond the forest sector and requires integration in a holistic way into development activities.

The ILO has acquired substantial expertise in forest worker and supervisor training through studies and field projects in Fiji, Pakistan, Zimbabwe and elsewhere. The concept of skills testing and certification has been implemented successfully in several countries. To improve working conditions as well as safety and health and to lay a basis for training, the ILO forestry sector work promotes the concept of national codes of forest practices. There have also been positive experiences with approaches to labour inspection in forestry.

More specific to the EIIP is the work done as part of the public works programmes of the ILO in the 1990s. Forestry projects in particular have generated various manuals and guidelines.[13] The work on forestry is a component of the EIIP work on environmental preservation and improvement and on land conservation and productivity, as part of the creation of green jobs in rural areas through labour-based works.

13 ILO: *Tree nurseries: An illustrated technical guide and training manual* (Geneva, ILO, 1989). Johansson, K. and ILO: *Planting trees: An illustrated technical guide and training manual* (New York, UNDP, 1993).

## 2.9 Summary

The poor of the world will suffer most from climate change. Plans, programmes and projects to mitigate the impacts of climate change need to be formulated, implemented and sustained.

Proofing and adapting infrastructure to climate change presents a different paradigm. Massive investments will be necessary. There are still choices to be made in how these investments will be used for infrastructure development. Previously, local resource-based approaches were promoted as providing additional employment and income benefits in the future. With climate change, these approaches provide a means to limit the dramatic effects climate change will have on rural livelihoods. It will no longer be an issue of merely providing additional employment but of ensuring that some of the jobs and livelihoods inevitably lost in agriculture due to climate change can be replaced by jobs in proofing and adapting infrastructure.

This chapter identifies the areas in which the ILO could provide support to communities in adapting infrastructure to cope with the impact of climate change. The ILO's local resource-based approach to rural infrastructure would provide specific benefits that would also alleviate the economic and social impacts on the rural population. These benefits range from employment and income generation to community capacity building, the development of local contractors and improving the capacity of local government organizations.

The following chapter provides ways in which local resource-based approaches can be applied in the five key areas identified in this chapter. Chapters 4–8 relate to each of those areas and offer some design parameters for technical programmes.

3

# A local resource-based approach to climate change adaptation

# A local resource-based approach to climate change adaptation[1]

This chapter describes the local resource-based approach to infrastructure[2] development and indicates how it can be used in climate change adaptation.

## 3.1 The local resource-based approach

Infrastructure plays a major part in the adaptation to climate change. Given the scientific evidence for climate change, it seems clear that the world is in the process of suffering from progressively more floods and droughts caused by the rising temperatures. This will have serious impact on affected communities. Rural

1 Adaptation in the context of this guide includes climate proofing, strengthening of existing infrastructure and adapting the design of new infrastructure to cope with climate change. It also includes activities that will improve the environment and water and land productivity.

2 In the context of climate change adaptation, infrastructure refers to physical infrastructure in particular, irrigation and drainage structures, water conservation and soil protection measures, flood control structures and rural roads.

infrastructure will be particularly badly hit. This is partly because such infrastructure may not be built to very high standards but also because the institutions and procedures to deal with these major changes are either weak or do not have the capacity to deal with the impact. In addition, new infrastructure and improved designs are needed to cope with the local effects of climate change.

Three types of interventions will require major and sustained attention:

- climate proofing of existing infrastructure to combat the increased levels of climate variation and frequency of floods and droughts;
- additional or new infrastructure constructed according to new criteria, dictated by the expected changes in the climate; and
- major public works programmes to contribute to environmental preservation and improvement, soil and water conservation and land productivity to deal with the different effects of climate change.

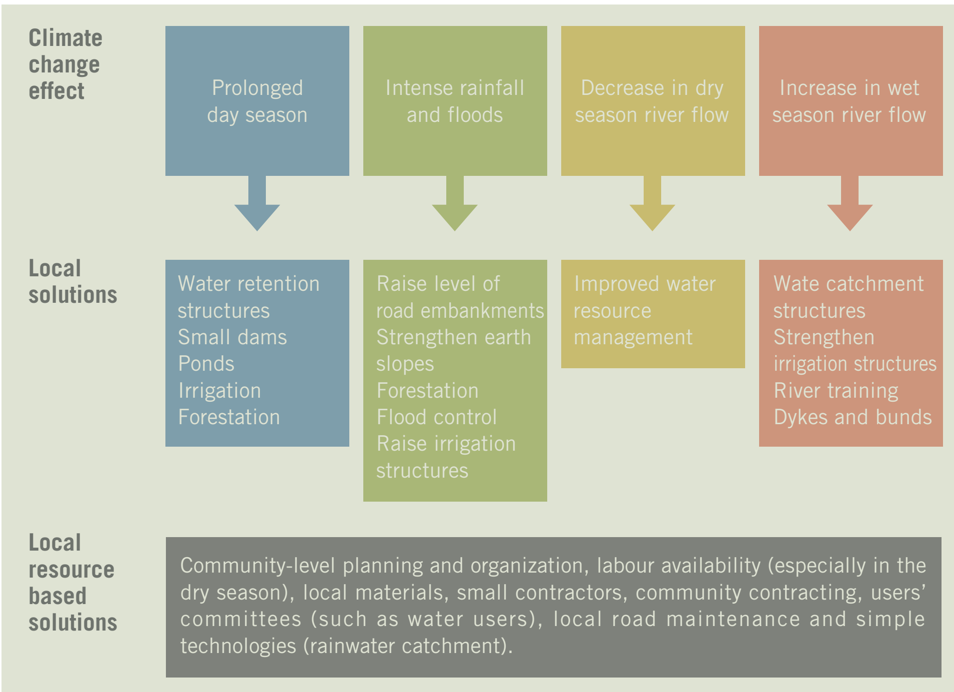
The infrastructure sector is a major area for resource allocation in any country. It is generally accepted that infrastructure and in particular rural infrastructure can be a vehicle for supporting the achievement of the 2015 MDGs if a pro-poor approach is adopted. Infrastructure also has significant potential for the use of local natural and human resources, to create decent jobs, to support the local economy, to strengthen local commerce and to promote transparency and participation. It is vitally important that the existing investment in infrastructure is protected, or climate-proofed, and that new or rehabilitated infrastructure is built to withstand the impact of the changing climate.

The ILO pioneered a local resource-based approach for developing local infrastructure. This approach emphasizes local participation during the identifying, planning and use of local resources, including labour, materials and enterprises for implementing and maintaining local infrastructure. The combined use of local participation in planning with the use of locally available skills, technology, materials and appropriate work methods has proven to be a technically efficient and economically viable approach to local infrastructure works in developing countries. Today, this approach to infrastructure planning and development is being mainstreamed in a number of countries as part of government strategies for effectively providing social and economic services and creating employment.

In general, the ILO sees the infrastructure sector as an opportunity to influence investments for increased impact, such as:

- improved targeting (reaching the poor);
- improved participation (negotiation);
- increased use of local resources (labour, contractors, materials and skills); and
- increased sustainability (preserving pro-poor investments through effective maintenance systems).

In general, the approach needs to be applied at three levels. First, policies need to be in place to encourage the use of local resources. Second, there needs to be strategies that permit the policies to be translated into action. Third, tools, procedures and work methods are required to ensure that the implementation of the works achieves the required output while maximizing the benefits to employment and income generation.



## 3.2 Policy framework


The application of a local resource-based approach is not merely the use of certain tools, procedures and systems. A policy framework conducive to the use of these tools and inclusive of the communities that the infrastructure serves needs to be in place. The government policy in relation to infrastructure would need to be sympathetic to the use of employment-intensive methods and the development of community or private contractors. Community participation should be an integral part of the planning process and is considered critical for local governance.

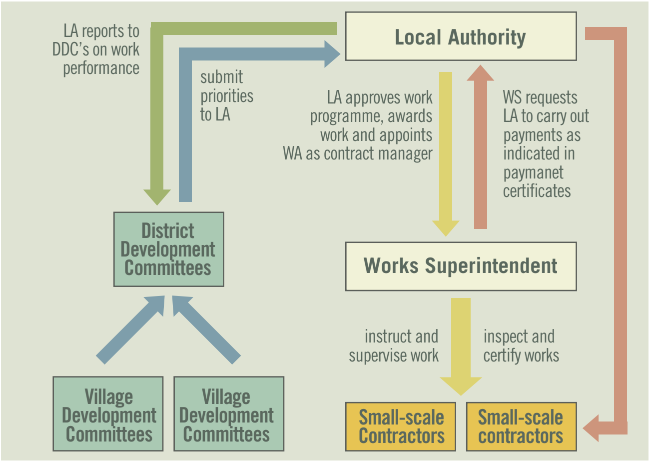
The ILO has worked with governments to help create a policy framework that allows the local resource-based approach to flourish. Clearly, some aspects, such as the development of the local construction industry and the more inclusive planning process, are developed as part of overall government policy and not specifically in response to the use of a local resource-based approach. Nevertheless, the ILO has helped put labour-based methods on the policy agenda in the Philippines, supported local contractors in Cambodia and Lao PDR and provided evidence-based cost comparisons between equipment and local resource-based approaches in Indonesia.

A policy framework for local infrastructure sets out a government's priorities for investments and the way to realize them. In parallel, a supportive legislative and regulatory model needs to be in place. For example, if the policy and strategy framework envisages local infrastructure development through contracting to small-scale local contractors and communities, the legislation to allow them to bid for works should be in place. Procurement rules and procedures should be sufficiently coherent and simple to understand.

There is no doubt that climate change adaptation works and improvements of existing local infrastructure will be a significant element in government programmes. Given the benefits of a local resource-based approach to infrastructure and public works in general, it is important that government policies are aligned to support this approach.

## 3.3 Institutional setting

The institutional arrangements that are in place for the planning and implementation have a strong impact on local infrastructure. A strongly centralized system tends to favour large-scale projects planned and implemented with limited local involvement. Decentralized systems, on the other hand, provide the opportunity for greater local involvement and the potential for planning and implementation to respond to the real needs of communities. Over recent years, there has been a strong move towards the decentralization of government administration in the Asia-Pacific region. Responsibility for local level infrastructure and increased funding has been passed to the decentralized government bodies. In general, this means that a local resource-based approach should be more appreciated and easier to implement.




At the decentralized levels, infrastructure planning is seen more in terms of an inter-sector activity. This allows all types of infrastructure, such as roads, clinics, schools, irrigation and water-supply schemes, to be planned in an integrated manner and may achieve a better reflection of the real demands of communities. In addition, the local authority can more effectively promote community involvement and the communities can more easily demand such involvement. When funds are disbursed at the local level, they can relate much more to the actual needs, and budget allocations are seen in relation to the overall budget and works programme of the local administration.

Governments, development banks and donors all seek to maximize the impact of their investments on poverty reduction. Local infrastructure is recognized as a crucial element in these efforts. Equally, decentralization is seen as a major opportunity for applying local resource-based approaches. The ILO views the local resource-based approach as both developing infrastructure, which has a supportive role in poverty reduction, but also as having direct impact on poverty reduction measures by providing income and employment. The local resource-based approach stimulates participation at both village and local government levels and links the two processes of decentralization and infrastructure provision. In doing so, it facilitates and supports the political process of decision-making and resource allocation. This in turn supports government decentralization and the move to greater transparency and accountability. The ILO has placed major emphasis on supporting local governments in infrastructure development in several countries.[3]

**Potential of local resource-based work methods**

*The local resource-based approach can help communities in identifying and implementing projects and create green jobs through:*

- *projects that contribute to environmental preservation and improvement, soil and water conservation and land productivity*
- *cash-for-work and labour-based activities (such as strengthening communities and public infrastructure and building capacity and improved and new infrastructure (flood protection, drainage, embankments and dykes)) to mitigate the impact of future natural disasters and climate change*
- *projects as part of the local resource-based strategy promoted in rural road works, which optimize the use of local resources, minimize the use of machines and use environmental-friendly construction technologies*
- *projects as part of urban slum development strategies to improve working and living conditions in low income settlements.*

## Capacity of local institutions

A major constraint to the effective delivery of services at the decentralized level is the capacity of the local institutions. Greater responsibility is given to local managers, administrators, planners and engineers. This in turn means that they need to have the capacity to respond. For example, because much of the work implementation is passed to local contractors, the local administration needs to have the required skills to effectively administer contracts. Fortunately, many countries that have decentralized government administration are now emphasizing the development of the required capacity at the decentralized level.[4]

Central line agencies tend to resist decentralization efforts on the grounds that the local authorities are not in a position to implement programmes effectively. In practice, however, it has been found that placing responsibility with the local authorities can provide the incentive to improve their skills. Nevertheless, for a variety of reasons, the capacity of local authorities tends to be a limiting factor in the implementation of programmes. Funds for capacity building have not reflected the demand;

3 See G. Edmonds and B. Johannessen: *Building local government capacity for rural infrastructure works* (Bangkok, ILO, 2003).

4 An example is the Philippines in which a separate programme in the Department of Interior and Local Government has been running since decentralization in 1991 to provide local governments with the requisite skills

qualified staff have often perceived working at the local level as a barrier to their career development; and political interference has restricted the initiative of the local authority staff. Capacity building for climate change adaptation is a new field that will require joint efforts from local and national governments and development partners.

Perhaps the major element of the ILO's work on local resource-based approaches has been in developing the capacity of local institutions. With climate change, the challenge to local authorities is greater, having to deal with several sectors, including irrigation, water and soil conservation, flood control, rural transport and forestry in a coordinated manner. A local resource-based strategy can respond to those challenges in terms of providing efficient approaches to planning and design, works implementation and maintenance.

***The local resource-based approach applied in tsunami-affected areas in Indonesia***

*The ILO has been assisting the Government of Indonesia with the development of national and local policies and strategies for sustainable rural infrastructure development. This collaboration has resulted in a local resource-based infrastructure development approach in community infrastructure planning, small-scale contracting and labour-based technologies. Rural infrastructure development for poverty reduction and employment creation has now been integrated into the national development agenda. Collaboration with different universities has resulted in a series of technical manuals. The approach has demonstrated its appropriateness and effectiveness and is now applied in the rehabilitation of rural roads in crisis-affected areas. In addition, more durable pavement design and construction methods are now deployed to withstand new climate extremes in the region.*

## 3.4 Implementing issues

The local resource-based approach to infrastructure provision is integrated in that it deals with the totality of the process of infrastructure provision, from planning through maintenance. In so doing, it not only addresses detailed technology issues but also the general institutional framework within which local resource-based methods are applied.

### Planning

Local infrastructure includes roads, bridges, tracks and trails, waterways and landing facilities, water supplies, schools, health centres, markets and irrigations schemes. They have in common that they are small-scale and respond to the needs of the local population. Local infrastructure facilitates services and performances of all sectors. It is also recognized as an enabler for a range of poverty-reduction measures. Rural roads, for example, provide the opportunity for children to have easier access to schools, for rural people and women in particular to more easily obtain medical services; for farmers to transport their crops to market and to have access to farm inputs.

Building on the defined needs and understanding of communities and assisting them in identifying priorities is essential to develop effective programmes of adaptation through infrastructure and other public works. A recent ILO project in the Philippines on flood control through community contracting provides a good example (see chapter 6 on flood control).

The ILO has been working over the past two decades to develop participatory, local planning tools to improve the allocation of infrastructure resources and to include the access needs of the poor. Appropriate procedures have been developed and successfully introduced in a variety of countries. The procedures and tools are relatively inexpensive and easy to use, pay attention to participation at the community and local government levels, identify the access and infrastructure needs of the poorest communities and

strengthen the existing local planning processes.[5]

An important aspect of these approaches has been capacity building. The ILO has developed special tools to identify the capacity building needs at the local level for rural infrastructure planning and development.

In responding to the need for local infrastructure adaptation, it is important that there is an integrated approach to planning. Adaptation of local infrastructure, such as rural roads, irrigation and flood control and drainage, should not be planned in isolation from each other. There is often a close interdependence among different types of infrastructure. This is important in the context of adaptation because the primary issues are not sector specific. Increased floods and drought have an impact in all sectors. Consequently, an inter-sector approach is required.

In most countries, there has been a transfer of development responsibilities to local governments as part of a decentralization process. The ILO's participatory infrastructure planning tools have been developed to be applied in a local governance context and thus strengthen decentralization efforts. The tools are very appropriate for adaptation programmes because they are both participatory and tailored to the needs and capacity of local governments.

Much has been written regarding the benefits of participatory planning and community involvement in development programmes. Both have become embedded in the development lexicon. In the case of climate change adaptation, both will be instrumental in the success of the planning of programmes due to the knowledge and understanding of communities of the changes taking place. As well, this knowledge can be fed into a process that defines the priority needs in an integrated approach and identifies appropriate and affordable interventions that will address the needs for climate change adaptation. Over the years, the ILO has developed considerable expertise in the development of procedures for community involvement in infrastructure works.[6]

## Technology

The choice of technology is important because it determines to which extent local labour and skills will be used, the amount, type and quality of equipment to be allocated, the amount of foreign exchange required and the use of other local

5 C. Donnges: *Improving access in rural areas: Guidelines for integrated rural accessibility planning* (Bangkok, ILO, 2003).

6 J. Tournée and W. van Esch: *Community contracts in urban infrastructure works: Practical lessons from experience* (ILO, 2001); and ILO: *Community infrastructure in urban areas: Creating jobs while improving low income settlements* (Bangkok, ILO, 2008).


resources. Experience has shown that for the same level of investment in local infrastructure, between two and four times more employment can be created, foreign exchange requirements can be significantly reduced and the overall cost is competitive with conventional-equipment intensive methods.

In an approach to infrastructure that intends to maximize the use of local resources, the use of local labour is an obvious target. The use of labour in construction works is of course commonplace. However, the ILO has shown that labour can execute many activities that would conventionally be carried out by equipment. Indeed, it has shown that labour can be efficient and effective to such an extent that it becomes the main means of production. This has led to the term "labour based" being used for these techniques.

Labour-based technology can be defined as the construction technology that, while maintaining cost competitiveness and acceptable engineering quality standards, maximizes opportunities for the employment of labour, together with the support of light equipment and with the use of locally available materials and resources.

In both economic and social terms, labour-based methods are beneficial. It is well documented that for low-wage economies, labour-based methods can be cheaper than equipment-based methods for a range of infrastructure, including rural roads, small-scale irrigation, water supplies and soil conservation. In addition, the techniques put money into the local economy in the form of wages, provide skills development and reduce the foreign exchange component of construction works and the longer-term reliance on spare parts and fuel for equipment.

It is evident that labour-based methods produce higher levels of short-term employment in construction works and longer-term employment for maintenance works. However, this emphasis on the employment issue has sometimes resulted in the methods being seen in terms of their social safety value, to the detriment of the creation of productive assets. Labour-based methods, as part of an overall local resource-based approach, afford the possibility to bring concepts of decent work, local participation, equal opportunities and poverty-oriented strategies.

The approach adopted by the ILO is to see labour-based methods as one part of an overall local resource-based strategy. Moreover, such a strategy has to be developed within the overall framework of infrastructure provision. The delivery of infrastructure requires a financial, administrative and managerial framework. In these circumstances, trying to impose a particular technology without thoroughly understanding the framework is likely to fail.

On the other hand, decentralization provides an opportunity for the development of a local resource-based approach, given that decisions are made at the local level, potentially relying on the resources that are available in the area. By understanding the framework and working with the local officials to build their capacity within that framework, it is possible to develop procedures that maximize the use of local resources.

Predictions on climate change suggest that it will have a serious effect on agriculture, where most rural livelihoods are focused. It is predicted that there will be an overall reduction in rural employment opportunities. A labour-based approach could have an important employment impact for the rural poor.

## Contracting

A local resource-based approach implies maximizing the use of local skills. There are many advantages to involving the private sector in rural infrastructure development, the most important being that it constitutes a valuable implementing capacity. Consequently, the ILO's approach has been to promote the development and use of local contractors. When contractors are convinced that labour- based methods are appropriate for specific works, then two objectives – developing the local contracting sector and providing employment to local people – can be achieved.

Decentralization permits greater use of local contractors, who can be recruited in the vicinity of where the works take place. If the works are organized in smaller contracts, it is possible to attract local firms already operating in the vicinity. In relation to climate change adaptation through local public works, the use of local contractors can generate both skills and employment. And they can be mobilized more quickly.

Local contracting can have an important role in implementing and maintaining infrastructure services. However, a thriving local contracting industry needs the development of a supportive environment.

Often contract management procedures applied at the local level are based on large contract works. They have stringent conditions relating to the financial condition of contractors and in relation to their ownership of equipment. This can preclude local contractors from tendering for work. Without threatening the contracts, it is possible to produce contract management procedures that are more favourable and appropriate for local firms. It may also be necessary to provide training to local contractors. This is a controversial issue, with some critics arguing that it is improper to use public money to support the private sector. However, the counter argument is that a thriving private sector is in the interest of the country and the economy and the investment is therefore justified.

It is important to establish an efficient contract administration capacity in local government agencies. Tools and procedures have been and will continue to be developed by the ILO to promote the involvement of small-scale contractors.[7] Using these tools in Cambodia, for example, the Government developed both the contract management capacity of the provincial governments and developed local contractors so that they could manage a US$30 million labour-based rural infrastructure project. This was at a time, in the late 1990s, when very limited capacity existed either in the local private construction sector or at the provincial government level.

There are of course many modalities for local contracting. The most common is the use of established contractors who bid competitively for works. However, for infrastructure works at the village level, contracts with communities or communities providing contracts to small contractors have been a feature of recent programmes. This is significant, given that works for climate change adaptation typically will be focused at the community level. In addition, the maintenance of infrastructure can be dealt with by communities, user groups or by the use of small contractors.

Community contracting is a term used to describe the direct involvement of the community in their own infrastructure improvement works. The extent of the community's responsibilities varies, depending on the situation and the contracting model used. The aim is not only to assist the community in accessing improved services and infrastructure but to promote capacity building and to provide experience in negotiating with government and non-government partners and in organizing and contracting. For the poor to participate meaningfully, they must be convinced that, ultimately, they will benefit. A vital component of the approach therefore is to bring awareness to the communities of what they can develop.

Various models of contracting are possible. In particular, the community must consider, with its partners, what type of contract arrangement is best for a particular construction project. Options include engaging the community as the contractor, mobilizing groups within the community as the contractor or using the conventional approach of hiring the services of small or large construction companies.

There are several options as to how community contracts should be set up. The answer is usually found in consideration of the capacity of the community, the levels of support available, the alternative sources of service provision, the technical complexity of the infrastructure to be provided and the responsibility of the municipal authority.[8]

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7 See for example: ILO: *Contractor's handbook for labour-based road works* (Roads Training School, Roads Department, Ministry of Works and Supply, Republic of Zambia, 2004); A. Thongchai: *Small-scale contracting: Strengthening local capacity for sustainable rural infrastructure* (Bangkok, ILO ASIST Asia-Pacific, 2004); B. Johannessen: *Building rural roads* (Bangkok, ILO, 2008).

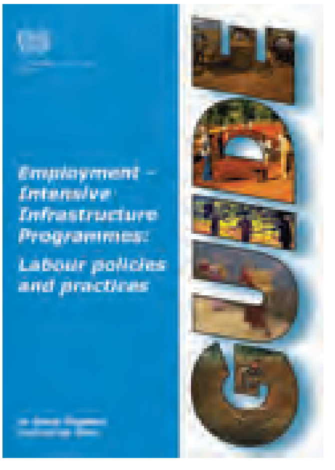
8 ILO: *Community infrastructure in urban areas: Creating jobs while improving low income settlements* (Bangkok, ILO, 2009).

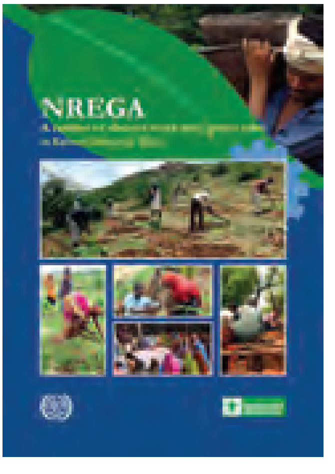
The demand for climate change adaptation measures is huge, and to address the sheer size of the challenge, the question of implementation capacity will arise. In these considerations, it is important to take into account all the good capacity found locally, including local government and communities as well as the private sector.

## Good labour policies and practices (decent work and green jobs)

The construction sector has a reputation for a lack of adherence to basic labour standards. For this reason the ILO has prepared a guide for local resource-based infrastructure programmes to assist both public agencies and the private sector to ensure that these standards are met.[9]

There are a number of basic labour standards that should be respected in all cases, whether the works are executed directly by government, by private contractors or through community contracts. These comprise minimum wage, minimum age (prohibition of child labour), non-discrimination (of women, religious or ethnic groups etc.), prohibition of forced labour, workers' compensation for work accidents, safety and health, and conditions of work for casual labour. There are risks involved with the introduction of a local resource-based approach, in particular regarding the employment of labour. To introduce the approach without considering labour issues may lead to the abuse or exploitation of workers. This, in turn, will jeopardize the large-scale application of programmes of this nature in the long term, unless relevant labour regulations are developed and applied. Particularly when the private sector is involved, efforts should be made to safeguard basic labour standards. A strategic use of the tendering and contract system will enable improved conditions of work for the large numbers of unskilled, temporary workers employed in these programmes by small-scale firms.




The ILO guide on Employment-Intensive Infrastructure Programmes presents examples of recent experience on how labour issues are being dealt with in the context of local resource-based infrastructure programmes and provides guidance on how to work with both the public and private sector on standards and working conditions.

9 D. Tajgman and J. de Veen: *Employment-intensive infrastructure programmes: Labour policies and practices* (Bangkok, ILO, 1998).

In the planning and implementing of local infrastructure, both local institutions and communities need to be made aware of the likely long-term impact of climate change. The local resource-based approach provides the opportunity to introduce good labour practices when applying climate change adaptation works.

## 3.5 Sustainability

In general, infrastructure tends to be poorly maintained. This is often because there is far greater interest in constructing than maintaining, partly because the users and the producers have the attitude of fixing something only when it is broken and partly, related to this attitude, because funds for maintenance are siphoned off to other "more important activities".

The rationale for maintenance is clear – the basic objective is implicit in the word itself. It is done to ensure that infrastructure is kept close to its original condition. It is accepted that over the life cycle, it will deteriorate due to factors that maintenance activities will need to address. Maintenance is organized as a preventive measure, and for this reason starts from the day the construction works are completed.

The aim of regular and timely maintenance is to ensure that the infrastructure remains serviceable or, at least, to increase the life of the infrastructure by putting off the date at which it needs to be reconstructed. This has several benefits, the most important being that it stretches the period over which the benefits of the investment made are available and thus provides a higher rate of return on the initial investment. In addition, it delays the day when large investments are required for reconstruction.

When constructing infrastructure for climate change adaptation, it is important to impress on all parties involved, but particularly communities, the need to set aside time and resources for maintaining the works. There are many models for the maintenance of local infrastructure, and several entail forming user groups and community organizations. The crucial issue is to ensure that maintenance is planned and carried out from the moment that the works are completed and that resources and an organization are ready to ensure that it takes place. This will be particularly important as the impact of climate change is felt. Infrastructure strengthened or constructed to reduce the impacts of climate change needs to be maintained on a regular basis. Given the limited funds that are generally set aside for maintenance, the onus will often fall on water user committees, local road maintenance committees and community organizations.

## 3.6 Gender

Gender is an important but largely neglected aspect of infrastructure planning and provision. Rural women pay a particularly high price for the lack of infrastructure in time spent accessing water, processing food, collecting firewood and reaching health services for themselves and their families. This "time poverty" limits their ability to develop or access complementary sources of income.

Women are in charge of keeping kids in school; and school enrolment is directly linked to quality of access to schools. Women take sick family members to health facilities, clinics and hospitals. The frequency of visits to such services is also directly linked to the quality of access to such services. Women are also responsible for preventive health care, immunization, check-ups, medical advice, sanitation, etc. Access to such services determines their frequency of use. In addition, women are in charge of collecting potable water. All these require good access to social infrastructure facilities, be it the road to the clinic or primary school or the buildings in which these services are housed. Women typically live and work at home. The home environment is therefore the chief of their concerns. Facilities such as good drainage, flood control, water wells and proper sanitation are more important to them. These facilities will figure prominently in programmes of climate change adaptation.

Rural infrastructure programmes can and must enhance women's participation and benefits – as workers during construction and as beneficiaries of the assets created.

In programmes that target local infrastructure that will support poverty-reduction objectives, it is important to recognize that women are typically the most vulnerable members of society. Destitute women, divorcees and other female heads of households are among the most disadvantaged. Thus women need equal opportunity to participate in and benefit from the development programmes.

With the changing climate, women's daily responsibilities are likely to become more difficult in affected areas. In particular, obtaining water, whether potable for drinking or for household use, obtaining fuel for cooking and having access to medical and education services, is likely to be more problematic. It is also crucial that women are fully involved – that their opinions are heard – in any decision-making processes regarding the planning and prioritizing of infrastructure.

Moreover, in the maintenance and operation of infrastructure assets, it is necessary to engage women because those structures are typically more important to them and thus they are more motivated to keep them in good condition.

## 3.7 Capacity building

Despite the benefits of a local resource-based approach, a pivotal issue is the capacity of those involved. This applies to the decentralized public agencies that will be tasked with the planning, budgeting, supervising and monitoring of the works, the communities involved in all stages of the process and the private-sector entities responsible for executing the works.

As noted, communities will need to be informed of the likely effect of climate change on local social and economic development issues. The selection of local infrastructure works for climate change adaptation would generally be based on the demand voiced by the users of the infrastructure most affected by the impact. This implies not only that they be fully involved but also that they are provided with the capacity to make appropriate choices in relation to the size and scope of irrigation, flood control, access roads, water conservation and drainage works.

Local government bodies will need procedures for planning and managing that will respond to those demands. In addition, they will require the capacity to deal with the budget, design and procurement issues related to the large-scale investments required for climate change adaptation.

The local private construction sector in general often needs support, both in terms of business skills but also in the technical details related to various works. Such support will need to be expanded so that the private sector has sufficient capacity to take on its future role in climate change adaptation.

Given that much of the work will involve communities, it will be important to provide them with the relevant training for the work for which they will be responsible. Much of this may not be formal training but provided in their locations through NGOs. For local government agencies and for the private sector, more formal training will be needed.

In general, the training material for such capacity building already exists, much of it developed by the ILO as part of their local resource-based programmes. Nevertheless, programmes of climate change adaptation through local infrastructure will need to include significant resources for staging the required training programmes.

## 3.8 Good governance

The advantages of making decisions at the lowest possible level are clear in terms of accountability, but the main challenge lies in the lack of human capacity, finance and other resources for both government and the private sector at the local level. Often, decentralization takes place in response to political pressure and has little local ownership. In some instances, decentralization appears to be seen by central governments as a way of reducing their responsibility for and involvement in subsectors, such as local infrastructure. Responsibility will sometimes be devolved without any real attempt to ensure that those levels of government have the funds, skills or systems to undertake their new tasks.

As a public good, local infrastructure has particular problems in decentralization. There can be a lack of coherence among the different parties involved. There is a tendency to use equipment-intensive methods rather than local resources. There is often also a preoccupation with new construction to the detriment of maintenance.

The ILO has been working for some time to increase greater understanding and recognition of the problems inherent in decentralization in the context of rural infrastructure development; to promote lesson learning between countries and sectors; and to support the decentralization process in individual countries.[10]

The issues concerning local infrastructure that need to be addressed in relation to good governance at the decentralized level can generally be categorized as institutional capacity building, such as:

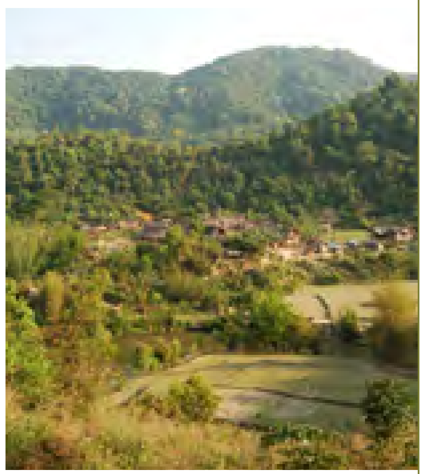
- developing skills of government staff;
- developing appropriate management procedures;
- defining and setting technical and quality standards for rural infrastructure works;
- building effective organizations for the management;
- supporting small and medium-sized contractors;
- establishing local planning and programming procedures that enable communities to ensure that their priorities are addressed by local government; and
- developing sustainable maintenance systems.

All these issues will need to be addressed when developing the capacity to manage climate change adaptation works programmes

10 G. Edmonds and B. Johannessen: *Building local government capacity for rural infrastructure works* (Bangkok, ILO, 2003).

## 3.9 Summary

The impact of climate change will affect us all. However, when sea defences fail, when floods overrun the protection structures, when drainage structures are unable to cope with the mass of water and, conversely, when water becomes scarce, it will be the poor who will be at greatest risk. It is clear that the major burden of the necessary adaptation to climate change will fall on communities. Flood control and drainage systems need to be both strengthened and developed, water conservation through more expanded water collection in the wet season needs to be improved and access roads are needed to lift residents above the projected flood levels.



It is not sufficient for local people to rely only on interventions from the central government. There is capacity at the local level and willingness to use it. What is required is support to what does exist and to maximize the impact of that local capacity in limiting the impact of climate change on people's daily activities.

Chapter 2 illustrates some examples of communities developing their own responses to climate change. These of course are important. They tend, however, to be ad hoc and often supported by donors as isolated projects. The scale of the effect of climate change calls for a much more concerted effort. Systems and procedures need to be put in place that are standardized and respond to the certain knowledge that infrastructure programmes for climate change adaptation need to become part of the annual government budget. No longer is it possible to react to the effects of climate change. It is critical that programmes put into place are proactively designed to deal with climate change.

Programmes focused on local infrastructure are best handled by the agencies that deal with such infrastructure on a daily basis. Moreover, they are more successful if they involve those whose lives are directly affected by the works being created.

Programmes of infrastructure adaptation will consistently be the responsibility of local governments. The clear message is that these decentralized organizations must be provided with the capacity and the resources to follow through with these programmes. In addition, the systems and procedures should be based on the actual needs of the communities and involve them from the planning stage through the provision of sustainable maintenance.

A local resource-based approach to infrastructure development can be a major contribution to assisting communities adapt to climate change. The ILO Employment Intensive Investment Programme has developed and demonstrated a range of tools that can be used in the planning and executing local resource-based approaches in rural infrastructure development. Guidelines and training manuals are also available for capacity building of the public and private sectors for delivering rural infrastructure investments.

The following five technical chapters look at possible climate change adaptation works in the primary subsectors: irrigation, soil and water conservation, flood control, rural transport and forestry. The five chapters reflect the local resource-based strategy described in this chapter.

4

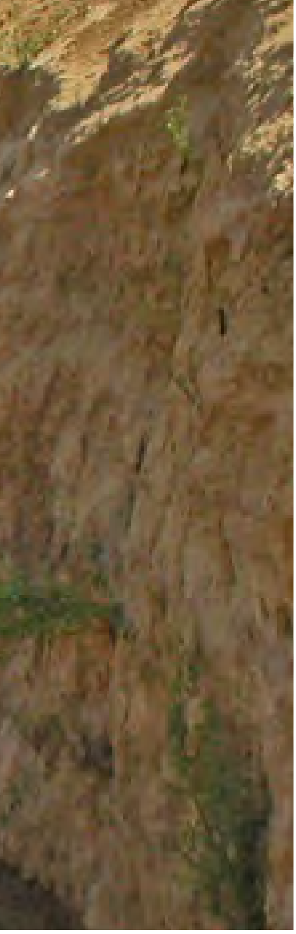
# Irrigation

# Irrigation

## 4.1 Irrigation and climate change – an introduction

Irrigation is the controlled application of water to arable lands to supply water requirements not satisfied by rainfall.[1] It is vitally important to the world's food supplies. Globally, irrigated land makes up only about one-fifth of the total arable area, but it produces two fifths of all crops and close to three fifths of cereal production (1 billion

1 National Oceanic and Atmospheric Administration, National Weather Service glossary, http://www.weather.gov/glossary/



tonnes of grain annually). Irrigated land yields two to three times more than rain-fed land as a result of higher yields per crop and because it allows multiple crops to be grown each year.

Agriculture is important for all countries in the Asia-Pacific region. More than 60 per cent of the economically active population relies on agriculture for their livelihoods. With their dependants, this totals 2.2 billion people. The region accounts for over two fifths of global crop production and for one-third of total cereal demand.[2] Irrigation is very important, accounting for 34 per cent of cultivated land in the region. This compares with 18 per cent globally, 10 per cent in North America and 6 per cent in Africa. In fact 70 per cent of the world's irrigated area is in the Asia-Pacific region.[3]

In South Asia, average rainfall varies greatly, with a regional average of about 1,300 millimetres per year. Irrigation coverage is therefore high, varying from over 80 per cent of farming land in Pakistan to at least 30 per cent in Afghanistan, Sri Lanka and India. In India and Pakistan, irrigation supports the production of major crops, such as sugarcane, rice and wheat. In Nepal it is used for rice. In East Asia, there is rather less use of irrigation so that in China and the Republic of Korea, cereals other than rice are often only rainfed. Even so, irrigation coverage averages over 30 per cent. In Central Asia rainfall averages less than 500 millimetres annually. More than half of the countries in this subregion irrigate at least 50 per cent of their cropland. This is essential for food production and for employment. South-East Asia receives over 2,000 millimetres of rainfall on average each year (second only to the Pacific subregion), so agriculture is largely rainfed; irrigated land is approximately 17 per cent of the total farmed area.[4]

The role of irrigation is expected to increase still further in the future. Developing countries as a whole are likely to expand their net irrigated area,[5] from 202 million hectares in 1997–1999 to 242 million hectares by 2030. Most of this expansion will occur in land-scarce areas where irrigation is already important. In South and East Asia, 152 million hectares, one-third of the total area of arable land, is already irrigated. This is expected to increase to 180 million hectares, or two fifths, by 2030.

2 United States Department of Agriculture: 2010. *Global crop production analysis* (Washington, DC, USDA Foreign Agricultural Service, 2010), http://www.pecad.fas.usda.gov

3 International Water Management Institute and FAO: *Revitalising Asia's irrigation to sustainably meet tomorrow's food needs* (Bangkok, FAO, 2009).

4 Asian Development Bank (ADB): *Building climate resilience in the agriculture sector in Asia and the Pacific* (Manila, 2009).

5 This is a net projection, in the sense that land lost due to for example salinization and water shortages, will be compensated by rehabilitation or by substitution of new areas.

## Water use for irrigation

Worldwide, irrigation now uses approximately 70 per cent of all water extracted for human use. It also represents 90 per cent of consumption use, meaning water that is not available for reuse further downstream. The water used for irrigation globally is equivalent to about 2 per cent of annual precipitation over land. In developing countries, an average 7 per cent of renewable water resources are used for irrigating. However, the proportion is much higher in Asia, with as much as 36 per cent of renewable water resources used in South Asia. Water availability will become a critical issue when the proportion of renewable water resources used, referred to as water stress, reaches 40 per cent. This is the level at which countries are forced to make difficult choices between their agriculture and urban water supply sectors.

Globally, there is still room for the expansion of irrigated land, with an estimated 402 million hectares available in developing countries, according to FAO.[6] Only half of this is being used currently. The picture is different in Asia, however; by 2030, East Asia is expected to be using two-thirds of its irrigable land, and South Asia (excluding India) almost 90 per cent. In Asia, the available water resources will be a major factor limiting expansion. By 2030, South Asia is expected to be using 41 per cent of its renewable freshwater resources.

A large proportion of the irrigation water is obtained from groundwater, accounting for half of the irrigation supply in South Asia and perhaps two-thirds in the grain belts of northern China. The risk of water shortage will become greater, and different sectors will be in competition for the use of the limited available water resources. In Asia, irrigation expansion will thus require significantly greater efficiency in water use.

## Climate change and irrigation

As previously mentioned, climate change is expected to lead to higher average temperatures as well as to higher and more concentrated rainfall in some areas. It will also result in longer and more severe dry periods in other areas, with a consequent higher frequency of droughts and floods. Inevitably these changes will have a severe impact on irrigated agriculture, affecting the working of existing and planned irrigation systems. They will also affect the demand for irrigation water: decreasing demand in certain areas but increasing demand in other areas, including those not currently using irrigation. An expansion of the area under irrigation will be needed to ensure water availability throughout the growing season and to keep crop production at the same levels.

The effects of climate change are already evident in the Asia-Pacific region in a number

6 FAO: *World agriculture towards 2015-2030: Summary report* (Rome, 2002).

of ways. Recent decades have experienced consistent warming trends, together with more frequent and intense extreme weather events. The entire region is expected to become warmer as a result of climate change. The situation regarding precipitation is less clear. The greater part of the region is expected to get wetter, although Central Asia and northern India are exceptions. Rainfall will tend to be heavier during wet periods, increasing the risk of flooding, while dry seasons will remain dry or get drier, resulting in a higher frequency of droughts. The region is also expected to experience more frequent extreme weather events. The map below shows where (irrigated) agriculture will be most severely affected, either as a result of lower precipitation, melting of glaciers or rising sea levels. The increase in precipitation and runoff intensity is not shown on the map but is expected to affect much of Asia and the Pacific.

Figure 4.1: Impact of climate change in Asia and the Pacific


Source: United Nations Environment Programme (UNEP): *Climate in peril: A popular guide to the latest IPCC reports* (Nairobi, 2009).

## Agricultural yields

Developing countries in the Asia-Pacific region are likely to experience the highest reductions in agricultural production in the world due to climate change. By 2050, the reduction in yield is expected to be in the range of 14–20 per cent for irrigated paddy. Corresponding reductions in yield for other crops are: 32–44 per cent for irrigated wheat, 2–5 per cent for irrigated maize and 9–18 per cent for irrigated soybean.[7] A study carried out by the Research and Development Institute of Khon Kaen University in Thailand has already recorded a 45 per cent reduction in Hom Mali rice production in recent years. These forecasts of yield reductions are primarily the result of the temperature rises and do not take into account possible effects of climate change on the availability of irrigation water.

## Irrigation water demand

Large changes in irrigation water demand, as a result of climate change, are expected in the Asia-Pacific region. The higher average temperature will lead to higher evapotranspiration (the loss of water to the air through evaporation and transpiration by the plant), resulting in higher water requirements. Although the increase in $CO_2$ levels in the air will increase the efficiency of water use by plants,[8] the effect is likely to be small; the higher temperatures are expected to result in an overall increase in the water requirements of crops.

In less well-watered areas, the rise in temperatures will increase evapotranspiration and lower soil moisture levels, thus increasing the need for irrigation water. It is estimated that agricultural irrigation demand in arid and semi-arid regions of Asia will rise by at least 10 per cent, for an increase in temperature of 1°C.

In wetter parts of the Asia-Pacific region, evapotranspiration will be less adversely affected because it is significantly influenced by humidity. Furthermore, the expected increase in precipitation will reduce the proportion of crop water requirements that must be met by irrigation. In many subregions, this will be greater than the increased crop evapotranspiration.

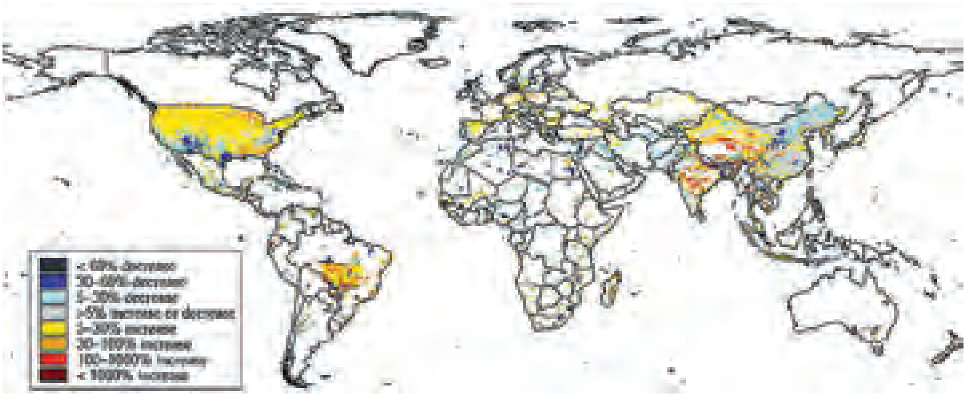
Increased intensity and variability of precipitation will, however, lead to increased irrigation water demand, even if the total precipitation during the growing season increases or remains the same. This is because a large proportion of it will occur in large storms and will be lost as runoff, without being available to the crops. The risk of periods of drought is also intensified, and irrigation will increasingly be needed to cover water requirements during such droughts.

7 ADB: *Building climate resilience in the agriculture sector in Asia and the Pacific* (Manila, 2009).

8 The higher $CO_2$ levels will allow the plants to take up $CO_2$ more easily with smaller openings of the stomata, which in turn will lead to less water loss through transpiration.

Arable land that is currently rainfed will also see increasing demand for irrigation (figure 4.2). This will be partly in areas that no longer receive sufficient precipitation to support rainfed agriculture as a result of climate change. It will also occur in wetter areas where the increase in variability of precipitation will result in drought periods, during which supplementary irrigation is required to ensure proper crop growth.

Figure 4.2: Relative change of annual net irrigation requirement from 1961 to 1990 and then 2025



Source: IPCC: "Summary for policymakers. Climate change 2001: The scientific basis", *Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, Cambridge University Press, 2001).

Overall and despite an expected average increase in precipitation in the Asia-Pacific region, irrigation requirements are expected to increase by as much as 15 per cent by 2020. (In comparison, global irrigation demand is expected to increase by only 3 per cent by 2020 and 7 per cent by 2070).[9] The increase in irrigation water demand will be mostly in the drier parts of the region, although greater intensity and variability of precipitation will also result in an increase in irrigation demand in some wetter areas. The ADB forecasts that the average irrigation requirement is likely to increase in East, South-East and Central Asia and to decrease slightly in South Asia.[10] Peak irrigation demands are also predicted to rise due to rising temperatures and droughts.

## Irrigation water supply

As well as the increasing need for food crop irrigation, there is the issue of water availability. Water for irrigation is taken from rivers, lakes, reservoirs and groundwater – all of them are part of the local hydrological cycle. Climate change will have a direct impact on this cycle, including water availability, and thus affecting agricultural production (both irrigated and rainfed).

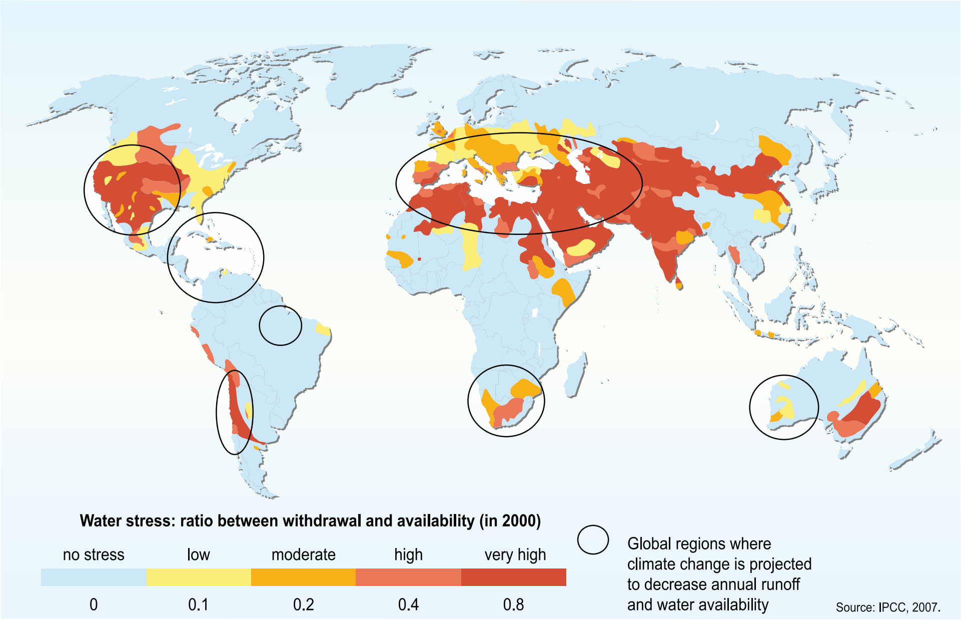
As noted, climate change is expected to lead to increased annual precipitation in most

9 B.C. Bates, et al. (eds.): *Climate change and water*, Technical paper,Geneva, IPCC Secretariat, 2008.

10 ADB: B*uilding climate resilience in the agriculture sector in Asia and the Pacific* (Manila, 2009).

of the Asia-Pacific region. The exceptions are Central Asia and northern India, where it is expected to decrease. All other things being equal, such an increase should lead to an increase in the renewable water that becomes available as groundwater or surface water discharge. Figure 4.3, however, shows that despite this increase, water stress levels (the percentage of the renewable water being used) are expected to become very high in Central, South and East Asia. This is because water use will increase and because the increase in the renewable water will not be spread evenly throughout the year.

Figure 4.3: Water stress and climate change




Source: UNEP: *Climate in peril: A popular guide to the latest IPCC reports* (Nairobi, 2009).

The expected increase in intense rainfall and other precipitation will lead to greater seasonal variation in the amount of water flowing in river systems. More intense rain during the monsoon and the consequent flash floods will result in a larger proportion of runoff reaching the sea and less reaching groundwater aquifers. The recharge of aquifers will therefore be limited, even where precipitation increases, and thus reduce the groundwater available for irrigation. Irrigation depending on surface water will also be affected by the higher variability of rainfall. Maximum surface flows may be higher as a result of intense rainfall, but only a small part will be used for irrigation. This will be followed by the lower minimum and base flows during subsequent periods of drought.

The maximum monthly flow of the Mekong River, for instance, is projected to increase by 35–41 per cent in the basin and by 16–19 per cent in the delta. The lower value relates the years 2010–2038 and the higher value to 2070–2099.[11] In contrast,

11 Compared with 1961–1990 levels.

the minimum monthly flows are expected to decline by 17–24 per cent in the basin and by 26–29 per cent in the delta.[12] The higher flow values will tend to coincide with periods of heavy rainfall, when there is less demand for irrigation water, while the lower flow values will tend to coincide with periods of drought, when the irrigation demand is at its maximum. The greater variation of flow in rivers is likely to have an important effect on irrigation systems dependent on them.

Glaciers in the Himalayas and Central Asia are already melting as a result of climate change. This brings potential short-term benefits from increased water available to irrigation systems taking water from rivers fed by them, although it also increases the risk of flooding. Runoff during warm and dry seasons will enhance while glaciers shrink, but it will drop dramatically after the glaciers disappear. In the long run, changes in snow and glacier melt, as well as rising snowlines in the Himalayas, will affect seasonal variation in runoff, causing water shortages during dry summer months. Water supplies stored in glaciers and snow cover are expected to decline in the course of the twenty-first century. This will reduce water availability during warm and dry periods in regions supplied by melt water from major mountain ranges. At lower latitudes, especially in South-East Asia, early snowmelt may cause spring flooding, resulting in an increase in the ratio of winter to annual flows. It will also lead to summer irrigation water shortages due to a reduction in low flows. One quarter of China's population and hundreds of millions in India are likely to be affected.

As noted, water stress levels are already high in Asia, especially in South Asia, making many countries in the region sensitive to climate change and to extreme weather events. The expected increases to high stream flows and reductions to low stream flows due to intensified precipitation, together with a reduction of the buffering capacity of glaciers and snow, is likely to lead to an increase in irrigation water shortages during parts of the year.

Another difficulty is that demand for non-irrigation water is expected to double from 2000 to 2050. Growth will be even greater in South Asia, outpacing that of East Asia. This will further increase water stress levels and the competition for water, both between the agricultural sector and urban water use, but also within irrigation systems.

In conclusion, an expansion of the irrigated area will be needed in response to higher temperatures and less predictable rainfall. Reductions in water availability may make this impossible, unless action is taken to improve irrigation efficiencies and to increase the replenishment of surface and groundwater sources.

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12 ADB: *Building climate resilience in the agriculture sector in Asia and the Pacific* (Manila, 2009).

### Flooding

Although too little water leads to vulnerability of crop production, the expected increase in rainfall, and especially the expected increase in its intensity, is likely to result in more frequent and more severe flooding. This will be made worse by higher stream flows from melting glaciers and snow. Such flooding may damage irrigation infrastructure as well as the irrigated crops. Even where flooding does not take place, heavy rainfall may lead to excessive soil moisture. It may also delay and disrupt farm operations and plant growth, especially the ripening and harvesting of cereals.

## 4.2 Adaptation of irrigation infrastructure

As the preceding section indicates, climate change in Asia is likely to result in an increase in irrigation demand. This is a result of greater plant water requirements, more droughts and, in certain areas, a decrease in annual precipitation. Thus, there is an overall need for more water within existing irrigation systems. There is also a clear need to expand the irrigated area to ensure that food production does not decrease as a result of the negative effects of climate change on rainfed agriculture. Such an expansion inevitably includes large irrigation systems, but of possibly even more importance are small irrigation systems through which traditional rainfed agriculture can receive supplementary irrigation during drought spells.

Every irrigation system includes three basic components: the water source (generally a river, lake, reservoir or groundwater), the conveyance system (canals or pipes) and the field application. When expanding irrigated areas, the implications of climate change on all three components must be considered in detail to ensure sustainability.

Water availability for irrigation will not keep up with the increase in demand, and may even decrease as a result of climate change. Although precipitation levels are expected to increase in many parts of Asia and the Pacific, its higher intensity and variability, coupled with the melting of glaciers, is likely to result in greater variability in both surface water flow and in groundwater levels throughout the year. This will lead, in turn, to less dependable irrigation water supply. Given the high water stress levels in Asia, this limits severely the possible expansion of the irrigated area unless water supply can be increased or demand in existing irrigation systems decreased.

One solution to the problem of supply is to improve storage in a specific area. This can make the precipitation and runoff available over a longer period. As well as large reservoirs, multiple small dams and even on-farm ponds can be used. Groundwater recharge is also an important means of increasing storage. The treatment and use of urban wastewater can also provide additional water resources where these are lacking.

Improving the retention capacity of an area can slow down the runoff and avoid the precipitation flowing away without significantly recharging the groundwater or increasing the soil moisture content. Planting vegetation and applying water conservation techniques can do this. It also reduces peak stream flows, leading to less risk of floods and spreading the runoff over a longer period, thus allowing a larger portion to be used for irrigation. Water conservation and retention techniques are dealt with in more detail in chapter 5.

Decrease in water demand can be achieved by increasing the irrigation efficiency (the ratio between the water applied to the crop and the water withdrawn from the source). Currently, an efficiency of 40 per cent is considered reasonable, which means that 60 per cent of the water is not used by the plants but is lost in evaporation, seepage and runoff. The irrigation efficiency can be improved in the conveyance of irrigation water from the source to the field as well as in the application of the water on the field, either through infrastructure improvements or through better management. The reuse of excess runoff water from an irrigation system can also result in improvements to the efficiency.

A decrease in demand can also be achieved by decreasing the water application requirement, such as through changes that result in a crop needing less water. These adaptations include changes to the cropping pattern (planting earlier/later when evapotranspiration is lower or precipitation levels are higher, resulting in lower irrigation needs) and to the crops (less water demanding or drought-resistant varieties or crops). Because these adaptations are generally not infrastructure related, they will not be dealt with in this manual.

Apart from the adaptation measures related to higher water demands and lower water supplies, a final set of adaptation measures is related to the mitigation of flood damage on an irrigation system. This includes protecting the irrigation system from floodwater from outside the system as well as proper drainage of water within the system to avoid crop damage. It also includes effective maintenance and repairs of flood-related damage to the irrigation infrastructure.

### i) Expansion of irrigated area

The increased risk of drought and expected lower crop yields means that the area under irrigation must be increased if current production levels are to be maintained. This is especially so in areas where there will be less rain. Population growth makes this even more urgent, and there is little easily accessible fallow land available in the Asia-Pacific region. Most increased crop production must therefore come from higher yields, which requires new or expanded irrigation systems. In the design of such systems, account must be taken of climate change, especially its impact on water demand and availability. Increased evapotranspiration must also be considered. In the case of groundwater schemes, lower groundwater levels will lead to deeper boreholes and to higher pumping costs.

Increased precipitation in most of the Asia-Pacific region will result in rainfed agriculture becoming more viable, although the expected higher intensity and variability of rainfall will lead to more periods of drought. The irrigation requirements will not be high and will relate mainly to ensuring water supply to plants during periods of drought. This can be done at a relatively small scale by ensuring the availability only of sufficient water to cover the foreseen drought periods.

Those areas experiencing decreased or less regular rainfall will require increased investment in irrigation. This may involve the construction or expansion of complete irrigation systems with canal networks and possibly even reservoirs. In some cases this will involve large systems and major construction works. In others, where irrigation is only required during drought periods, it may only involve small surface water storage facilities or groundwater pumping facilities and the related distribution channels. This approach will be particularly important in the semiarid and arid areas of Central Asia, Afghanistan, parts of India and some of the Pacific Island states.

Any increase in the irrigated area is likely to increase the already high levels of stress on water and other environmental resources. This will become increasingly challenging as warming and evaporative demand increase. Increased demand for water by competing sectors will also limit the options for expanding irrigation. The energy cost of delivering water, especially when groundwater needs to be pumped, is a constraint, as are the additional greenhouse gas emissions that may be associated with modified cultivation practices. Using renewable sources for water extraction and delivery as well as the use of treadle pumps[13] would be helpful.

Badly designed expansion of irrigation may also lead to groundwater depletion, soil salinization and waterlogging. The risk of salinization will increase as a result of climate change due to higher temperatures and evaporation rates.

Any expansion in the irrigated area will therefore require improved storage to increase water availability, for irrigation and for other sectors. There will also be a need to improve the efficiency of both the new and the existing systems. These issues are discussed further on.

13 The Energy and Resources Institute (TERI) estimated for International Development Enterprises of India that the operation of one treadle pump annually reduces $CO_2$ emissions by 477 kilograms. See ADB. 2009. op. cit.



## ii) Improvement of water storage and sources

Greater variation in the timing of runoff due to climate change will lead to a need for increased water storage. This will allow more of the increase in precipitation and runoff water to be used for irrigation during periods of the year when it is actually needed. Increasing storage will be particularly useful in areas where the annual runoff does not decrease significantly and possibly even where it increases. The increased storage will allow runoff to be used more effectively and over a longer period of time.

This will require investment to expand large-scale storage by building reservoirs. Such reservoirs will allow the use of available water during abundant periods to be spread out over longer periods when water is scarce. In the design of such reservoirs, account needs to be taken of increased agricultural and other water demand. The design process must also consider likely changes to the hydrology because heavier, more intense runoff may carry more sediment. Additional measures, such as reforestation, may be required to avoid the accelerated silting of reservoirs.

The construction of small dams and reservoirs in individual small catchments may be a better solution in regions where changes in precipitation are highly uncertain. This

### *Irrigation in India's rural employment scheme*

*The National Rural Employment Guarantee Act (NREGA) in India aims to provide more secure livelihoods for people in rural areas. It guarantees 100 days of wage employment a year to rural households whose members volunteer to do unskilled manual work. The Act's objective is to create durable assets that help strengthen the livelihood resource base of the rural poor. These include irrigation, water conservation and harvesting, flood control and protection, drinking water and rural connectivity-related works.*

*Several hundreds of thousands of small-scale irrigation works are carried out each year. Most build or improve small dams or reservoirs and dig canals. The projects generally result in a significant increase in storage capacity, allowing for the expansion of the irrigated area. The resulting schemes are generally less than 20 hectares in size and provide the farmers with irrigation water during drought periods. They may also allow a second crop.*


Small dam built under NREGA

is especially the case where increased storage is intended to reduce the effects of short drought periods or provide supplementary irrigation. These could be dams that serve several fields and water users or individual ponds that are used by only one or a few families. Such ponds can also be developed within irrigation systems to supplement the primary source and ensure water availability during times of water scarcity at system level. They can be filled using irrigation water in times of abundance, runoff water or even rainwater in times of high precipitation. Such small-scale storage systems provide farmers with additional insurance in the event of drought conditions. Experience also indicates that numerous small-scale storage systems in a watershed can have similar effects on river flows and aquatic ecosystems as a large dam and canal irrigation.

When planning and designing reservoirs or dams, account must also be taken of health hazards that may increase as a result of climate change. Dam and irrigation programmes, for example, have been shown to increase malaria mortality. Temperature rise increases the occurrence of such diseases, which can also spread to new areas.

Water retention through water conservation measures also can slow down runoff and increase the storage of water in the soil that can then be used by crops over an extended period. Such measures include mulching, vegetative measures and contour bunds. They are described in greater detail in the following chapter.

The final method of storing water for irrigation is the recharging of groundwater aquifers. The particular approach adopted will depend on local conditions. Where macro pores exist to allow rapid recharge, it can be straightforward. Lakes, reservoirs and dams will be required, however, if recharge is slower. In some areas, recharge may be hindered by impermeable layers, and the natural recharging of the groundwater may take place in a different area altogether. Some community recharge initiatives in India have successfully reversed falling groundwater tables. Seepage from irrigation systems also can lead to the recharging of groundwater, and improvements in irrigation efficiency can, perversely, have negative effects on groundwater levels.

As well as ensuring the increased availability of groundwater for irrigation, groundwater recharge in coastal areas can also counter the intrusion of saline water into aquifers caused by higher sea levels. An advantage of groundwater recharge is that it can take place in a different location to that where it is used for irrigation, and no means of conveyance are necessary. The recharged groundwater can be used whenever needed and has high application efficiency because there are generally no losses in conveyance.

The use of wastewater near urban and peri-urban settlements can be seen as an alternative to increasing water storage, where this is not feasible due to precipitation levels, topography, geology or cost. In such cases, the proper treatment of water needs to be ensured to avoid negative health implications. The very strictest water-quality guidelines for wastewater irrigation must be applied to prevent health risks from pathogenic organisms and to guarantee crop quality. For this reason, it is of very limited applicability in developing countries. Currently, at least one-tenth of the world's population consumes crops irrigated with wastewater. Increasing water scarcity and food demand, coupled with poor sanitation, are likely to encourage the use of poorly or untreated wastewater, which would cause major health problems.

In conclusion, improved retention and storage of runoff water is required to increase the amount of water available for irrigation when it is needed. This will require the construction of large reservoirs. Small dams or ponds may be a more appropriate alternative in certain locations. The application of basic water conservation measures at field level will also be essential. This will improve surface water storage, soil moisture content and groundwater recharge, thus making more water available for the crops over an extended period of time.

### iii) Increasing irrigation efficiency

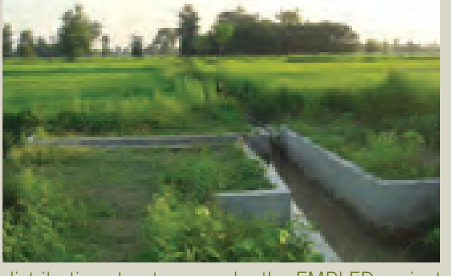
Storage improvement will help to solve the problem of higher water demand but will not always be sufficient on its own. In areas such as Central Asia and northern India, where precipitation levels are expected to decrease, complementary measures must be taken to improve the efficiency of water use. These include infrastructure adaptations as well as changes to management.

The "irrigation efficiency" of an irrigation system is the percentage of the water pumped or diverted through the scheme inlet that is used effectively by the plants. The

***Controlling water distribution and avoiding conflicts in Nepal***

*In the Kamala irrigation system in Dhanusha district in Nepal, the canals had only been developed up to secondary level. Each secondary canal served an average of 900 hectares of land. The lack of tertiary canals was a major problem for water distribution, and farmers were forced to break open secondary canals to enable water into their fields through simple flooding. This resulted in a lack of control and in large areas being flooded and included fields that did not need so much water, leading to water damage and waterlogging. This led in turn to very low efficiencies, with an average of only 40 per cent of the 12,500 hectares in the system being irrigated in the dry season. The lack of water for downstream farmers led to serious conflicts.*

*Under the ILO Employment through Local Economic Development (EMPLED) project, over 15 kilometres of tertiary canals were built, with inlets and outlets to the fields, and some existing canal sections were lined. Culverts were built under roads so that they no longer needed to be dug open whenever irrigation water was needed. The works were contracted out to the water users' association through its committees in the selected command areas. The works led to a significant increase in the efficiency of water use because the distribution could be managed more effectively using the new canals and distribution structures. Canal breaks also became less frequent, and conflicts were reduced as more water became available for downstream users.*



Construction of irrigation distribution structures under the EMPLED project

scheme irrigation efficiency can be subdivided into the conveyance efficiency, which represents the efficiency of water transport in canals between the source and the field, and the field application efficiency, which represents the efficiency of water application in the field.

FAO considers the efficiency of an irrigation scheme to be good if it is between 50 and 60 per cent. A figure of 40 per cent is considered reasonable; while 20–30 per cent is poor. In the Asia-Pacific region, irrigation efficiencies are generally low, at around 30 per cent. This means that in an average irrigation scheme, over two-thirds of the irrigation water is not used effectively. Losses occur through evaporation and deep percolation or seepage during conveyance from the source to the field. They also occur through evaporation and deep percolation in the field as well as through excess runoff into the drainage system.

The conveyance efficiency depends mainly on the amount of seepage and deep percolation. In the case of unlined canals, it depends largely on the type of soil. This efficiency varies from 90 per cent for short clay soil canals (less than 200 metres) to

60 per cent for long sand soil canals (more than 2 kilometres). The efficiency can be increased to around 95 per cent by lining the canals. This need not be costly concrete lining but could be masonry or stone paving. The efficiency can be improved further by using pipes, thus also avoiding evaporation losses, although the cost and required size of such pipes are often a constraint. Effective maintenance and vegetation control can also improve conveyance efficiency considerably by ensuring unrestricted water flow and avoiding loss of water from damage to the canals. The use of straight canals without unnecessary bends can also increase efficiency levels. All of these measures also reduce the incidence of stagnant water health-related hazards.

The application efficiency depends mainly on the irrigation method, the soil type and the field topography. The most common methods include surface irrigation, principally furrow and basin irrigation, as well as sprinkler and drip irrigation. Surface irrigation is sometimes also called flood irrigation. The big advantage of surface irrigation is its low-running costs because it relies on gravity. Sprinkler and drip irrigation need pumps to create the necessary pressure. Water losses at field level are usually the result of non-uniform levels of irrigation application (parts of the field receiving more water than needed so that other parts receive enough) as well as excess runoff of irrigation water.

A typical example is furrow irrigation, in which water is led through parallel furrows in a field with a mild slope. At the beginning of the field water starts to seep into the soil as soon as it enters the furrow, whereas at the end of the field, water only begins moistening the soil when it reaches the end of the furrow. To compensate for this time lag and to avoid waterlogging at the beginning of the field, the irrigation flow is often increased, resulting in a large proportion of the water flowing out of the furrow at the end of the field as excess runoff. This leads to low application efficiencies of around 60 per cent for furrow irrigation. Furrow irrigation efficiencies can be increased significantly by decreasing the water flow once the water has reached the end of the furrow, at averages of 75 per cent. Similar efficiencies are achieved with border irrigation, in which instead of furrows, borders are constructed to keep the water within narrow strips of the field. Border irrigation is generally used in fields with slightly steeper slopes and where machines are used.

In the case of basin irrigation, the field is divided into small basins that are level and surrounded by bunds to keep the water in. Water is allowed to enter the basin, which is submerged, resulting in a more uniform application. The application efficiency is higher and can reach levels of 70–80 per cent. This also reduces excess runoff because

it flows into neighbouring basins. Basin irrigation is used in flat land as well as in very steep areas where terraces are constructed. It is mainly used for rice cultivation.

With sprinkler irrigation, the water is not spread over the ground but through the air using sprinklers that work under pressure. Sprinkler irrigation is much more efficient than surface irrigation, with efficiencies of around 75 per cent or higher. The primary losses associated with sprinkler irrigation (other than those due to over-watering) are direct evaporation from wet soil surfaces, wind drift and evaporation losses from the spray, system drainage and leaks. Well-maintained sprinkler systems should have leak and drainage losses below 1 per cent, but poorly managed systems have shown losses of nearly 10 per cent. Sprinkler irrigation can be applied in both flat and sloping areas. It can be used for many soil types but is especially suitable for sandy soils. It is sensitive to wind and high temperatures and does need large investment in pumps, pipes/hoses and sprinklers. Low-cost alternatives exist that can make use of height differences in steep terrain for achieving the required pressure.

Drip irrigation also makes use of hoses, but a lower pressure is required. The drip system has small emitters along the hoses that provide continuous low volumes of water directly to the root of the plant. Drip irrigation is even more efficient and can reach 90 per cent if properly applied. When used with groundwater, drip irrigation can save over half the water and over a third of electricity, compared with flood irrigation. This is equivalent to an average reduction of 675 kilograms of $CO_2$ emissions per acre per year. Water with a lot of sediment can clog the emitters. Drip irrigation is particularly suitable for water with high salt levels because it avoids salinization. The required investments are relatively high for the hoses, emitters and pumps. It also tends to be more labour intensive due to the need to check that the emitters work properly.

As this section highlighted, the application efficiency can be improved by changing from flood irrigation to other methods, such as drip irrigation. Not all methods are applicable in all situations, however, and the choice will depend on the topography, slope, type of soil, type of crop and water quality. The adoption of sprinkler and drip irrigation is often limited by the higher intrinsic capital cost as well as higher labour costs and the technical skills required.

Achieving higher irrigation efficiency is not simply a matter of the irrigation method chosen or infrastructure. Good management, skills, knowledge and the motivation to save water are all important. In large parts of Asia and the Pacific, it is common practice to use surface irrigation, usually flood irrigation, and to submerge the entire field. Over-watering is probably the most significant cause of water loss in any irrigation system. Even with the best-designed system, efficiency will suffer if more water is applied than the crop can use beneficially. Very low efficiencies result from flood irrigation because of deep percolation (beyond the roots of the crop), evaporation of the wet surface area and runoff of excess water.

There is great potential for improving the efficiency of the different surface irrigation methods. A good example is the use of an alternating flow rate in the case of furrow irrigation. This can involve simply educating farmers about more efficient irrigation practices, without changing the irrigation method. Even when government or others promote water conservation, farmers may only use water sparingly when it becomes scarce or if other issues, such as time and labour, make them. If water is available and easy to apply, farmers will tend to use more than is necessary. Education should, therefore, be complemented by appropriate water-pricing mechanisms to encourage more efficient water use.

Further field efficiency gains can be achieved by conserving soil moisture through mulching, appropriate tillage methods and windbreaks to reduce evapotranspiration. Alternating dry-wet irrigation can further build crop resilience and conserve water while reducing emissions and fossil fuel use in the case of groundwater irrigation.

System efficiencies can be increased by improved management of the system and effective programming of the duration and rotation cycle of water use. Proper irrigation scheduling is important if high efficiencies are to be achieved and over-irrigation avoided.

At both the field and system levels, runoff of excess water is a major cause of water loss and irrigation inefficiency. This is especially true of flood irrigation. Runoff losses can be virtually eliminated with return-flow systems that capture the runoff water and direct it back to other fields. New irrigation systems should incorporate such return flows to increase system efficiencies.

In conclusion, changes in practice to increase the productivity of irrigation water use can provide significant adaptation potential for all land production systems under future climate change. At the same time, improvements in irrigation efficiency are crucial to ensure that water is available for both food production and competing human and environmental needs. More efficient water use in irrigation can also avoid problems with salinization and the release of drainage water that contains high levels of fertilizers and pesticides.

### iv) Mitigation of flood-related damage

Flooding and flood-related damage have not usually been taken into account during the design of existing irrigation schemes. With the likely increase in rainfall intensity, together with the expected melting of glaciers and snow caps, the risk of flooding will increase. New systems must take account of flooding in their design, and existing systems may need to be modified. The most common type of flood-related damage is waterlogging of the soil, causing a lack of oxygen in the root zone and consequent crop damage. Flooding may also damage irrigation infrastructure, especially river intakes.

Depending on the characteristics of a particular irrigation system, protection against flooding consists of ensuring that flood waters from outside do not enter the system and that excess water inside the system is adequately drained. The first situation may require the construction of protective dykes and embankments around all or part of the irrigation system, together with adequate flood control gates to allow the entry of irrigation water and the exit of drainage water. An important consideration here is that, although such dykes may protect the system against flood waters, the surrounding high water levels may also prevent the discharge of drainage water using gravity. The construction of temporary or permanent runoff-holding ponds within the system is one solution. Pumps could also be used to discharge the drainage water over the protective embankments.

With higher precipitation levels and especially where rainfall intensities are expected to increase, flooding within the irrigation system may be a problem. This makes an effective drainage system especially important. In many irrigation systems, drainage is already insufficient and certainly not up to the expected increase caused by climate change. Improved drainage will also help to avoid waterlogging and salinization. The on-farm storage ponds mentioned in the previous section can also act as a buffer for storing excess water during heavy rainfall, allowing its use at a later stage in case of drought. By ensuring that these ponds are empty at the beginning of the rainy season, they can be used to store excess runoff or else be filled with irrigation water at the beginning of the dry season.

## 4.3 A local resource-based approach to irrigation adaptation and expansion

In the case of irrigation, climate change adaptation mainly involves the expansion of the irrigated area together with the improvement of water-use efficiency. There is also a need for increased water storage and retention because of expected increases in crop water requirements, higher runoff intensities and drought risk. Flood control measures will also be important. A number of the adaptation techniques identified in the preceding section involve the construction, improvement and maintenance of infrastructure. Other management changes will also be needed.

Infrastructure-related interventions can and should be implemented using a local resource-based approach in so far as this can be done without compromising the cost or the quality of the work. The use of such an approach has the advantage of creating jobs and incomes as well as the physical infrastructure required to adapt to climate change.

This section looks at various issues relating to the implementation of a local resource-based approach, as described in chapter 3. It focuses on aspects of participation and planning, labour-based technologies, capacity building and contracting as well as maintenance and sustainability.

### Local participation and planning

Local participation in the planning for the construction of new irrigation schemes or the adaptation of existing ones is essential. Experience and research have shown the benefits of involving water users in the planning and design processes for new construction and for improvement works. This leads to greater efficiencies, especially in small-scale irrigation systems.

Local communities and water users are often in the best position to identify the impact that climate change has had in their area. Even if they do not fully understand the process of climate change, they have the most detailed knowledge of its impact. They know whether rainfall patterns have altered and whether droughts have become more frequent. They also know if surface water storage and groundwater levels have changed. By ensuring their participation in the design of new and adaptive works, this detailed knowledge can be used to intervene effectively.

Where water users' associations (WUAs) exist, they must be the principal focus of participatory planning. Where there are no WUAs, the communities or future users must be involved. Where WUA or community structures and representation systems are already strong, such participation can lead to very sustainable results. Where they are weak, technical assistance may be needed to ensure the proper representation and participation of vulnerable groups, including women, the poor and indigenous people. The creation of a WUA can also help to improve local participation more generally.

***Pioneering environmental protection into irrigation projects in Nepal***

*From 1986 to 1996, the ILO provided technical assistance to the Dhaulagiri Irrigation Development Project in the hill and mountain districts of Nepal's Western Region. The project started in 1989 with US$3 million from DANIDA, the Swedish development agency. The project was designed to use participatory approaches and employment-intensive techniques. The project introduced successful models for participatory planning, implementation and management of small-scale irrigation schemes. The models developed have been replicated widely in Nepal.*

*The project also pioneered the integration of comprehensive environmental protection measures into the planning and implementation of such works. This included the use of vegetative stabilization techniques, afforestation and river training works. A practical manual for planning, designing and implementing environmental protection measures was produced, with a particular focus on the use of locally available resources.*

*The project had a considerable impact and showed impressive long-term benefits in agricultural production, employment and income. The doubling of cropping intensities and yields were expected, leading to a doubling or tripling of beneficiaries' incomes. The local resource-based approaches and the use of appropriate technologies, combined with the injection of relatively large investments in the local economy, were very effective and triggered significant multiplier effects that reached far beyond the project area.*

*Evaluation studies also showed that the irrigation schemes developed with assistance from the project functioned better than government-operated schemes, which had no community participation. A significant factor was the organization of the beneficiaries into water users' associations.*

There are many differing demands for water from agriculture, drinking water, livestock and industry. This makes it essential that an integrated approach to irrigation planning and design be adopted, taking into account the different types of water use as well as the effects of increased upstream water use on downstream users. Effective watershed planning for overall water use has long been a goal of governments but has been difficult to put into practice in developing countries. Other integrated area-based planning systems, such as the integrated rural accessibility planning, have been more successful and can be used effectively for irrigation planning at a local level.

## Technology

The local resource-based approach promotes the use of local labour, materials and contractors where this does not compromise cost or quality. Management of labour is simplified through the use of task based remuneration systems, in which a fixed payment is given for a certain amount of output or task. These tasks are generally given to an individual or group and can include one or several days of work. The use of such an output-based system greatly simplifies the monitoring and planning of work. Examples of this approach for some of the main infrastructure works involved in climate change adaptation for irrigation follow further on.

Local resource-based approaches using local labour and materials are well suited to the construction of small dams and reservoirs. The dams are typically made of earth, although they may be partially reinforced with gabions and stone or brick masonry. The compaction of earth fill is best done using light mechanical equipment to ensure adequate quality. Plate and pedestrian vibrating rollers or rollers towed by tractors are ideal. Where fill material needs to be transported over a significant distance, the use of local tractors and trailers may be more cost-effective. Unskilled labour can be used with some minimal training and technical supervision. A lot of experience has been gained with the construction of small dams and reservoirs using such methods. ILO and others have developed guidelines and manuals. Work carried out under the National Rural Employment Guarantee Act in India has involved the building and improving of numerous reservoirs and dams using local labour and materials. Similar techniques can also be used for the construction of sinks or temporary storage facilities for drainage water.

***A reservoir project in India enables two crops***

*One of the many small reservoir and dam projects carried out under the National Rural Employment Guarantee Act in India was the improvement of the Mergha Nala reservoir in the village of Barachatarma. The reservoir was deepened to 7 metres, requiring the excavation of over 20,000 cubic metres of earth. The project created 17,500 workdays, at a cost of just under 1 million rupees (US$22,000). The reservoir is fed by rainwater runoff from the nearby Ajoydha hill and surrounding areas. It is used to irrigate 15 hectares of land, allowing a second crop to be grown where only one crop was possible before.*

The construction or widening and lining of canals for irrigation or drainage are also very suitable for labour-based approaches. The work consists mostly of excavation and simple concrete or stone masonry work. Excavation is particularly suitable for unskilled labour. For the lining of canals, minimum skill levels are required and local artisans or contractors can be used to ensure the proper quality. Mechanical equipment is generally not needed for canals and, except for cement and reinforcement, materials can be obtained locally.

***Benefits flow from a canal project in Nepal***

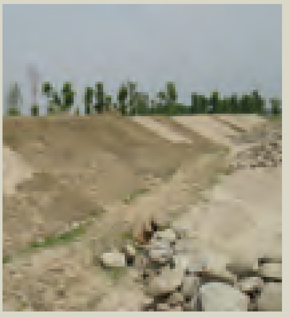
*The Dhairing Village Irrigation Project was one of the schemes carried out under the Dhaulagiri Irrigation Development Project in Nepal. It covered 85 hectares and served 350 families. The project diverted water from a river by cutting a canal along a vertical rock face. The farmers maintain the irrigation canal themselves and pay a small amount to a water committee. The canals were built using piecework so that the farmers felt ownership. In some cases local contractors were used but were chosen by the farmers' associations. Locally available materials, such as clay, were used, allowing the farmers to repair the canals without importing more expensive cement. Difficult maintenance in the future or a major mishap, such as a big landslide, should lead to intervention by the Department of Irrigation. A women's savings and credit scheme was associated with the project. The canals were built using employment-intensive techniques because it was not possible to bring machinery up the mountainside to the site. The main benefit of the scheme was the provision of regular water for the farmers' paddy and wheat. They could now have two paddy crops and one of wheat a year. A micro hydro-power scheme was also included.*

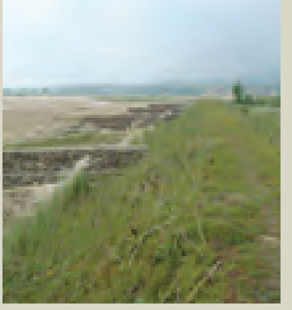
Soil and water conservation measures, such as bunds, gully control measures and water-harvesting techniques, are well suited to a local resource-based approach (see the discussion the next chapter).

Flood control, usually involves the building of dykes or embankments, either around the irrigation system as a whole or at critical points. River training may be needed to prevent changes to river courses. Flood control also often involves the construction of basic earth structures similar to dams. Where such structures are prone to erosion, as with river training, protection works must be used. Gabions are ideal for this, owing to their flexibility and low cost. The gabion mesh can be woven on site and stones can generally be found nearby. Required skill levels are also low, allowing the use of local labour with minimal training (see chapter 6 for more information on flood control measures and experiences).

### *Controlling flooding with female labour in Nepal*

*Flooding, leading to the loss of arable land, was a problem on the Kamala irrigation system in Nepal. Under the ILO EMPLED project a dyke, protected by gabions and vegetation was built along the Kamala River to stop the flooding. The work was contracted out to the water users' association who used local labour – 40 per cent of it female.*





Construction of flood control and river training measures under the ILO's EMPLED project

## Capacity building and contracting

In the case of existing irrigation systems, water users' associations are often already in place and are responsible for the management of the system. They must be involved in the planning and design phase and can also be contracted to implement the work. The relevant WUA is then responsible for organizing the labour, purchasing the materials and engaging subcontractors or other services. In some cases, the WUA will be competent and may already have experience with organizing and subcontracting. In others, technical assistance will be needed to ensure that work is done properly. In schemes where there is no WUA, it is recommended that one be established. This helps to ensure participation during planning and implementation. It also helps to ensure more effective operation and maintenance.

In the case of new irrigation schemes (especially small-scale schemes), community contracting can be used, enabling the future users to do the work. Localized projects with a direct benefit to a limited number of people, such as irrigation, are ideal for this approach. It also helps to ensure that construction complies with local customs, and that sufficient "ownership" and skills are developed for effective maintenance. Although community contracting needs more technical assistance, the long-term benefits outweigh the short-term costs of such support. The exact scope of the contract will depend on the type of work, the required skills and the existing competence of the individual communities.

***How water user participation pays off in India***

*In the 1990s, the ILO and DANIDA implemented labour-based infrastructure projects in two drought-prone districts in West Bengal and Tamil Nadu in India. Activities included water and soil conservation, rural roads, watershed management, irrigation, forestry and wasteland development. An integrated and participatory approach was used, with plans based on an assessment of local priorities and available resources. The infrastructure built provided long-term sustainable employment and contributed significantly to poverty reduction and the more efficient use of the local resource base.*

*An evaluation of the project showed high economic rates of return, and the proportion of poor households fell from an estimated 70 per cent to 53 per cent.*

*Greater emphasis was given to the participation of water users in the construction and management of the schemes than in comparable government schemes. This resulted in greater efficiency of water use: less wastage, larger areas irrigated in both wet and dry seasons, a greater proportion of high-yield paddy cultivated and more equitable distribution of water among farmers. The evaluation also showed that the prospects for sustainability were considered to be better in the ILO-assisted irrigation schemes.*

In larger schemes or where there is a need for more skilled work or mechanical equipment, the use of contractors can be considered. These can be small contractors or slightly larger contractors from nearby villages or towns. Except for some very specific irrigation works, local contractors will usually have the skills and equipment for the

type of works discussed in this chapter. Some basic training will likely be needed on quality control and the organization of labour.

## Maintenance and sustainability

Maintenance and sustainability are critically important in irrigation. Lack of maintenance often leads to less efficient use of water, and it can lead to part of the irrigation system no longer receiving sufficient water for crop cultivation. Poor water management as a result of a lack of maintenance can also lead to waterlogging and salinization of the soil, making it unsuitable for crop growth. The expected greater water demands and less water availability due to climate change means that effective maintenance will become even more important than currently.

Regular maintenance of the irrigation canals will ensure greater conveyance efficiencies. Regular maintenance of the drainage system will help to avoid flooding, flood-related damage, salinization and waterlogging. Maintenance in these cases is mainly vegetation control and de-silting to allow unrestricted flow through the canals. It will also involve repairs to fix any damage.

Dams, protective embankments and dykes will require maintenance to avoid damage, including erosion. Damage to dams can cause major problems if water levels rise suddenly due to heavy rainfall and runoff. This can lead to dams being breached and to severe flooding downstream, including loss of life.

Maintenance of most types of infrastructure is usually given very little attention in developing countries. In some sectors, such as main roads and water supply, maintenance promotion has led to improvements. In irrigation systems with many users and beneficiaries and little or no public funding, the financing and organization of maintenance continues to be difficult. A local resource-based approach can easily be used because generally only labour and some minimal material inputs are needed. The organization of maintenance through local enterprises or community groups formed and paid specifically for this purpose has been found to give much better results than voluntary labour contributions (in which the work is carried out according to the availability of the labour rather than to the need for maintenance).

Paying for maintenance can also lead to the creation of sustainable jobs, in addition to ensuring properly working irrigation systems with high water-use efficiencies. Involvement of communities and water users' associations during construction and rehabilitation tends to increase the sense of ownership and creates the necessary motivation and skills for ongoing effective maintenance.

The most common maintenance activities that can be carried out by groups or local enterprises and their required labour inputs are the clearing of vegetation in canals (400–500 square metres per workday), removal of sediment from canals (1.5–2.5 cubic metres per workday) and the repair of earthen or stone masonry canals (1–2 square metres per workday). Although it is possible to contract out the maintenance on an input basis, paying for the number of days worked, it is recommended that an output-based system be used. Payment is made based on the amount of work completed and on the productivity rates. Such an approach greatly simplifies planning and monitoring of maintenance, making successful implementation by WUAs more likely.

It is also possible to use a performance-based system, under which a maintenance group or local enterprise is given a fixed payment and is made responsible for ensuring the proper working (performance) of the system or part of it. Such an approach makes use of certain performance indicators (such as the maximum level of sedimentation in a canal or the allowable vegetation growth). As long as these performance indicators are met, the payment is made. The organization of the work is then the responsibility of the maintenance group or enterprise, and the WUA is only required to verify that the performance indicators are being met.

4

Irrigation

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5

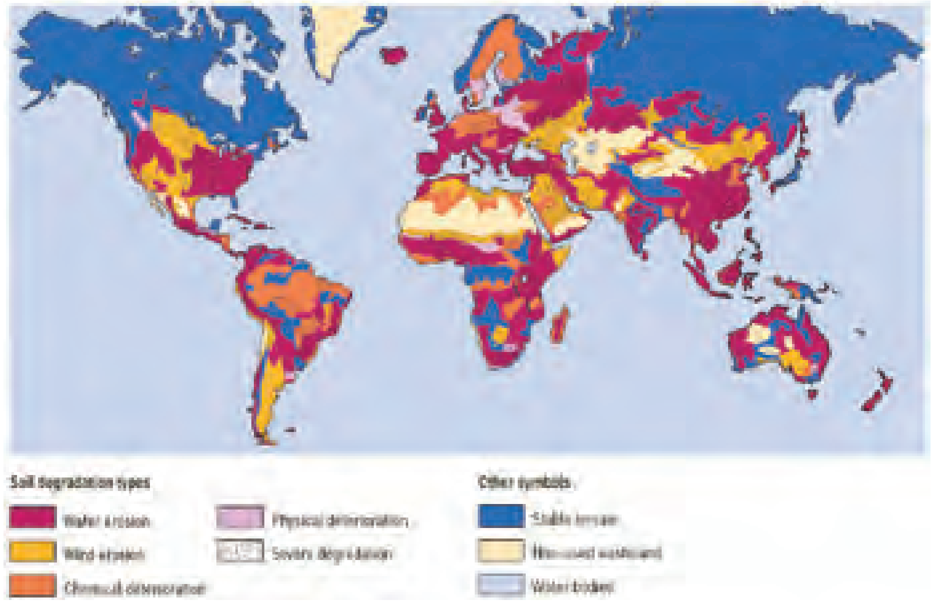
# Soil and water conservation

# Soil and water conservation

## 5.1 Erosion and water availability – an introduction

Loss of soil through erosion is one of the most important types of soil degradation.[1] It leads to lower nutrient levels, to decreased water retention capacity and, in some cases, to reduced rooting depth. Erosion contributes to declining agriculture productivity and thus to reduced income and livelihood opportunities from agriculture. It also has off-site consequences, such as siltation and flooding.

Figure 5.1: Soil degradation in Asia




Source: FAO: *World agriculture towards 2015-2030: Summary report* (Rome, 2002).

As well as good soil characteristics, agriculture is also dependent on adequate water availability during the growing season. For rainfed agriculture, this requires that adequate rainfall is stored in the soil and made available to the crop. Water availability

1 Other types of soil degradation include chemical degradation (such as salinization) and physical degradation (such as compaction).

in the soil is, of course, dependent principally on the amount of precipitation. It is also affected by the amount of water that is stored in the soil and the proportion of precipitation that is lost as overland runoff flow.

Erosion and water availability are strongly linked because increased water retention in or on the soil will lead to reduced runoff and erosion. Where water retention is lower, erosion by increased runoff will be higher. Low soil moisture content will also make the soil more susceptible to wind erosion. Water and wind erosion, in turn, further reduce the water-retention capacity of the soil, resulting in a self-reinforcing cycle.

The measures needed to conserve soil and water are also frequently the same or very similar in nature, which is why these two issues are treated together in this chapter.

## Soil degradation through water erosion

Water erosion is the process whereby soil particles are dislodged and transported by raindrops and surface runoff. Water erosion is generally divided into five main types.

Splash erosion refers to the impact of raindrops, falling directly onto the ground or indirectly from overhanging leaves. It results in soil particles being dislodged, broken down and transported aerially downhill. It is often characterized by the crusting of the soil and the formation of pedestals where stones protect the underlying soil.

Sheet erosion is caused by runoff water flowing over the soil in a uniform layer, removing the topsoil more or less evenly. It is less conspicuous but can be identified by the presence of large quantities of coarse particles and the exposure of roots. It is the most important form of topsoil erosion and results in large amounts of soil ending up in streams and rivers.

Rill erosion results where the flow path of the surface runoff is concentrated. The concentrated flow leads to higher velocities, eroding soil from these paths and transporting it downhill. This causes slight terrain deformation of a few centimetres deep that can be repaired by routine tillage operations. Although the impact of this form of erosion in terms of topsoil loss is much lower, it can still cause significant damage to crops and, if left unchecked, can result in gully formation.

Gully erosion occurs when the surface runoff flow is concentrated in narrow channels. Gullies are typically



0.5–1 metre deep but can easily become more than 30 metres deep. The main consequence of gullies is the loss of arable land area and the resulting difficulties caused to agricultural activities and access. Gullies can also cause significant damage to infrastructure. Specific soil conservation measures are required to repair gully erosion.

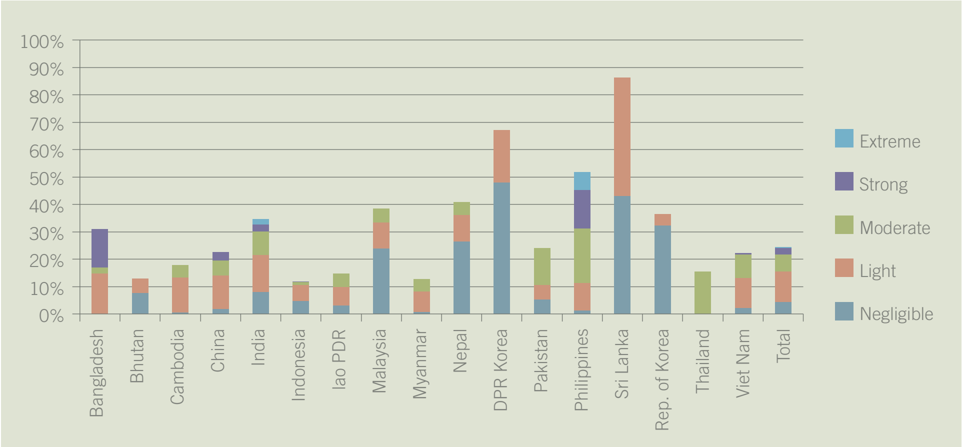
Riverbank erosion occurs where the water flow washes away the bank, causing both the loss of arable land and damage to infrastructure. Accelerated riverbank erosion is due to increased river flows and the result of sediment deposits in the river course. It is often caused by increased runoff and erosion upstream.

Water erosion results in the loss of fertile topsoil and deformation of the terrain (gullies, landslides, riverbank erosion), leading to a reduction in soil productivity and the loss of arable land. It also has off-site impacts through the deposition of eroded materials, resulting in fields and infrastructure being buried or damaged, reservoirs, irrigation systems and rivers silting up and water sources becoming polluted. Prevention of erosion has productivity benefits on-site and damage prevention benefits off-site.

A study on human-induced soil degradation in South and South-East Asia from 1995 to 1997 (ASSOD) found that the land area affected by water erosion was 451 million hectares (24 per cent of the total). Of this, more than three-quarters involved the loss of topsoil and the related decrease in productivity. One fifth involved loss of arable land due to terrain deformation, and only a small part (3 per cent) was due to off-site effects. (The study only considered soil deposits on fields, not damage to infrastructure). Over 167 million hectares (9 per cent of the total) were assessed as being affected by moderate to extreme water erosion (table 5.1). This is particularly important in Bangladesh (16 per cent of total land area), India (13 per cent), Philippines (40 per cent), Pakistan (13 per cent) and Thailand (15 per cent).[2]

2 International Soil Reference and Information Centre (ISRIC): *The assessment of the status of human-induced soil degradation in South and Southeast Asia* (1997).

Table 5.1: Severity of water erosion as a percentage of total land area

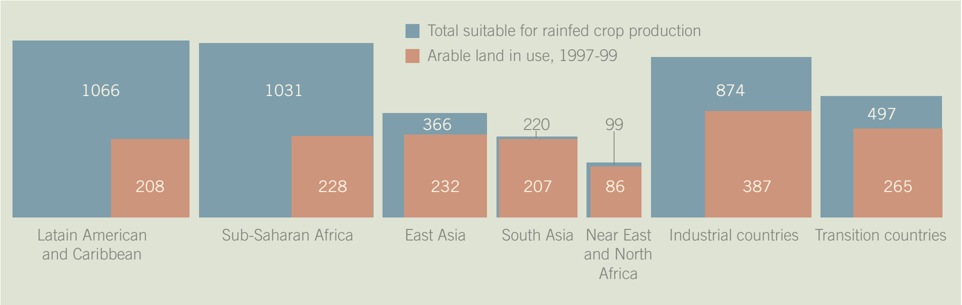



Source: ISRIC: *The assessment of the status of human-induced soil degradation*

FAO[3] estimated that in sloping areas, such as the hills and mountains of Nepal, 20–50 tonnes of topsoil per hectares are lost each year (equivalent to approximately 20–50 cubic metres of topsoil per hectares per year). In highly degraded watersheds, this may be as high as 200 tonnes per hectares per year. Yields in these areas are known to have dropped by 8–21 per cent in the period 1970–1995. The effect of erosion on productivity, therefore, can be very high, although this is strongly influenced by other factors, such as the type and depth of the soil and the application of fertilizers. The loss of arable land can also be an important factor, especially in Asia, where the percentage of arable land already in use is very high (94 per cent in South Asia) and the potential for expansion of the cultivated area is limited (table 5.2).

Soil erosion is influenced by a number of different factors that are best explained on the basis of the Universal Soil Loss Equation that is used to predict soil loss by water erosion.

Table 5.2: Arable land available and in use




Source: FAO: *World agriculture towards 2015-2030: Summary report* (Rome, 2002).

3 FAO: *World agriculture towards 2015-2030: Summary report* (Rome, 2002).

### *Universal soil loss equation*

*Soil loss = R x K x LS x C x P*

***The rainfall factor R*** *refers to the influence of rainfall and runoff. The kinetic energy of the initial raindrop impact has an important effect in loosening and breaking down the soil aggregates (and to a certain degree in their aerial transportation). Runoff subsequently occurs when the precipitation rate*[4] *exceeds the infiltration rate*[5]*. Therefore, if the rainfall intensity is greater, the portion of rainfall that flows over the surface as runoff will also increase. The infiltration rate of the soil also tends to decrease with time during a rainstorm, and as a result, longer rainstorms will result in higher percentages of runoff.*

***The soil erodibility factor K*** *refers to the susceptibility of soil particles to detachment and transport by rainfall and runoff. The susceptibility to particle disaggregation and transport is influenced by the texture, structure, organic matter content and permeability of the soil, as well as its moisture content. Soils with large aggregates and high organic matter content will be less susceptible to erosion and will also have less runoff due to their higher permeability.*

***The slope length-gradient factor LS*** *takes into account the slope of the land. Steeper slopes result in higher runoff speeds, causing more erosion. Longer slopes will result in the accumulation of greater volumes of runoff water, also leading to increased erosion.*

***The crop management factor C*** *depends on the type of crop, the cropping system and the planting system being used. It looks at the crop coverage in periods of different rainfall in terms of the ability of the crop to break the impact of raindrops, to hold the soil together and to slow down runoff speeds. It also takes into account any vegetative material covering the soil and protecting it against raindrop impact.*

***The support practice factor P*** *refers to the soil conservation measures being taken to reduce the impact of raindrops, increase infiltration, decrease runoff volumes and slow down runoff speeds. These measures are discussed in greater detail further on.*

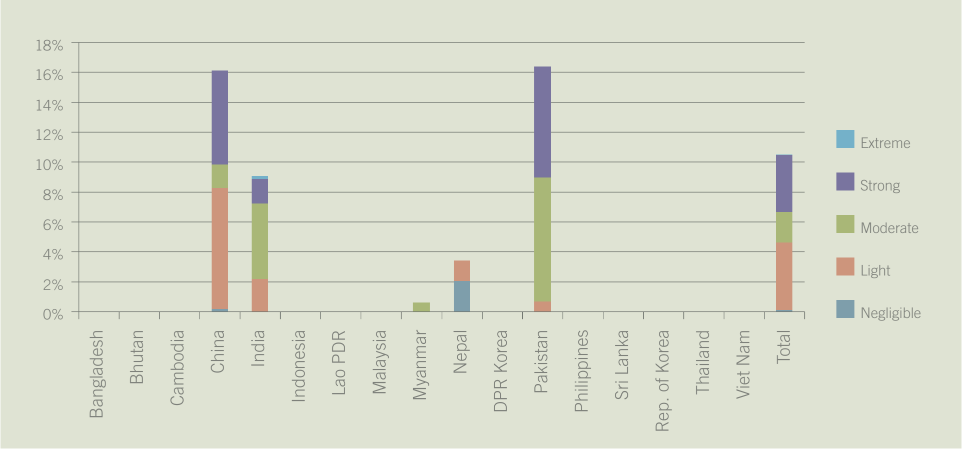
## Soil degradation through wind erosion

Wind erosion is the process whereby soil particles are picked up and transported by wind, sometimes over very large distances, even between continents. According to the ASSOD study, the area in South and South-East Asia affected by wind erosion is estimated as 194 million hectares, 11 per cent of the total land area in the region (table 5.3). Of this total area, 108 million hectares are moderately to severely affected. The effects of wind erosion are mainly on-site in the form of topsoil loss (52 per cent) and terrain deformation (41 per cent), with only a minor off-site impact (7 per cent). (This looks mainly at damage to farmland and does not take into account off-site damage to infrastructure.) Wind erosion is mainly a problem in China, India and Pakistan (figure 5.4).

4 The amount of rainfall in a given time, generally expressed as millimetres per hour.

5 The amount of water that can infiltrate into the soil in a given time, generally expressed in millimetres per hour.

Table 5.3: Severity of wind erosion as a percentage of total land area




Source: ISRIC: *The assessment of the status of human-induced soil degradation in South and Southeast Asia* (1997).

Wind erosion is caused by turbulent air movement just above the soil layer. Soil particles protruding into this turbulent airflow are particularly vulnerable to being dislodged by the wind. Where soil particles are larger or firmly attached to other particles, wind erosion is reduced. The transport of soil by wind is either through suspension, in which small soil particles are actually carried by the wind, or by saltation or creep, in which the soil particles make small jumps or roll over the surface but are too heavy to be carried by the wind. For all types of wind erosion and transport, wind speed and wind turbulence are the most important factors.

## Water availability and runoff

Water availability for crop growth is primarily dependent on the amount of precipitation during the growing season. In areas with insufficient rainfall during the growing season, additional water will be needed to ensure proper crop growth. Even where precipitation levels are high enough, only a certain proportion of precipitation will infiltrate the soil and become available as soil moisture or groundwater, with the remainder being lost as runoff. In locations where significant subsurface water flow exists, infiltrated rainwater may also be lost. The loss of rainfall as surface runoff or subsurface flow may leave insufficient water in the soil for use by the crop.

On sloping ground, runoff occurs when the precipitation rate is greater than the infiltration rate of the soil. In soils with higher infiltration rates, more rainfall can enter the soil and become available to the crop.

Where surface irregularities and micro topography stop or slow down the flow of runoff water, the amount of time the water remains on the soil is increased, thus also allowing a greater percentage to infiltrate into the soil. Many common agricultural practices can result in a reduction of the soil infiltration rate. Taken together with the removal of irregularities and micro topography by tillage, such practices result in higher runoff rates.

Where rainfall intensities are higher, the percentage lost as runoff is also likely to be higher. A few intensive showers will usually lead to less rainfall infiltrating into the soil than a larger number of low-intensity showers, even if the total amount of rainfall is the same, leaving less water for crop growth. The infiltration rate of a soil also tends to decrease as the soil becomes saturated, and longer showers can result in higher runoff rates than showers of short duration.

Apart from reducing the water availability upstream, runoff is also likely to cause erosion. The increased surface runoff will also lead to higher peak water flows in streams and rivers, leading, in turn, to a higher risk of flooding downstream. The eroded materials carried by the water can also cause sedimentation problems downstream.

Overall, increased runoff flows have detrimental on-site effects by reducing water availability for crop growth and increasing water erosion. They also increase susceptibility to wind erosion. Higher runoff volumes also have off-site effects, such as higher peak flows in streams and rivers, increased risk of flooding and damage to infrastructure. The runoff water also tends to carry high levels of sediment, nutrients and agricultural chemicals, causing sedimentation and pollution downstream.

## 5.2 The effects of climate change on erosion and water availability

As noted previously, the average annual rainfall is expected to increase in Asia, except for Central Asia, where a decrease is expected. The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) concludes that winter precipitation is very likely to increase in northern Asia and the Tibetan Plateau and likely to increase in eastern Asia and southern parts of South-East Asia. At the same time summer precipitation is likely to increase in northern Asia, East Asia, South Asia and most of South-East Asia but is likely to decrease in Central Asia.

The IPCC also concluded that this increase in rainfall will, to a large extent, be due to an increase in rain intensity and not as the result of more rainy days. The precipitation extremes will increase more than the precipitation means, and the frequency of extreme precipitation events is expected to increase everywhere. The IPCC concludes that there is very likely to be an increase in the frequency of intense precipitation events in parts of South Asia and in East Asia. Extreme rainfall and winds associated with tropical cyclones are likely to increase in East Asia, South-East Asia and South Asia.

Table 5.4: Projected increase in precipitation and extreme wet weather by the end of the century

| Region | Mean annual precipitation ( % increase/decrease) | Frequency of extreme wet weather (% increase) |
|---|---|---|
| Northern Asia | 15 % | 92 % |
| Central Asia | -3 % | - |
| Tibetan Plateau | 10 % | 46 % |
| East Asia | 9 % | 47 % |
| South Asia | 11 % | 39 % |
| South-East Asia | 7 % | 44 % |

Source: IPCC

A study by the Soil and Water Conservation Society,[6] found that the risk of erosion increases with higher rainfall levels because the increase in erosion risk is generally greater than the increase in precipitation. This is because a greater proportion of that precipitation is lost as runoff flow. As the accumulated quantity of rainfall increases during a precipitation event, the capacity of the soil to absorb the precipitation (infiltration) decreases and surface runoff increases. The study also showed that the increase in erosion is especially high where the increase in rainfall is due to more intensive showers instead of just more showers. Under such conditions, the increase in erosion can easily be double the increase in rainfall.

### *Increase in runoff and erosion due to an increase in precipitation*

*The Soil and Water Conservation Society study looked at different scenarios in which precipitation increase was the result of an increase in frequency of showers, due to an increase in intensity of showers or a combination of both. They found that a 1 per cent increase in precipitation wholly due to an increase in frequency resulted in 1.3 per cent higher runoff volume but only a 0.85 per cent increase in erosion. The same increase in precipitation due wholly to an increase in intensity resulted in a 2.5 per cent increase in runoff and a 2.4 per cent increase in erosion.*

| | Increase in mean annual precipitation | | | |
|---|---|---|---|---|
| | 5% | 10% | 20% | 40% |
| **Change in runoff** | | | | |
| Increase only in frequency | 6% | 13% | 26% | 51% |
| Equal increase in frequency and intensity | 10% | 20% | 39% | 79% |
| Increase only in intensity | 13% | 25% | 50% | 100% |
| | | | | |
| **Change in erosion** | | | | |
| Increase only in frequency | 4% | 9% | 17% | 34% |
| Equal increase in frequency and intensity | 8% | 7% | 33% | 66% |
| Increase only in intensity | 12% | 24% | 48% | 95% |

Source: SWCS: *Conservation implications of climate change: Soil erosion and runoff from cropland* (SWCS, 2003).

6 Soil and Water Conservation Society (SWCS): *Conservation implications of climate change: Soil erosion and runoff from cropland* (2003).

Given the results from the SWCS study and the fact that most of the increase in precipitation is expected to come from an increase in intensity, we may expect that runoff and erosion will increase approximately twice as much as the increase in annual precipitation. The increase in erosion may be even higher, as the increased annual rainfall is expected to go hand in hand with extended drought periods, indicating an even higher increase in rainfall during the wet season. Even in Central Asia a slight increase in erosion may be expected despite the decrease in annual mean precipitation, as winter precipitation is actually expected to increase and become more intensive.

Table 5.5: Projected increase in runoff and erosion by the end of the century

| Region | Increase in runoff and erosion |
|---|---|
| Northern Asia | 30 % |
| Central Asia | 5 % |
| Tibetan Plateau | 20 % |
| East Asia | 18 % |
| South Asia | 22 % |
| South-East Asia | 14 % |

Source: IPCC

These results only look at the direct effect of increased precipitation on erosion. The SWCS study also identified a number of indirect effects. The erosivity of smaller rainfall events is also expected to increase, especially in terms of gully and riverbank erosion, because extreme events are likely to destabilize soil and gully walls, making them more susceptible to erosion by subsequent smaller rainfall events. Also, the loss of large quantities of topsoil due to extreme events is likely to increase the erodibility of the remaining soil due to its lack of organic matter, resulting in a lower infiltration rate, less biomass production and less ground cover. The expected increase in drought risk due to climate change is furthermore expected to result in the average soil moisture content before an intense precipitation event being lower, making the soil more susceptible to splash erosion.

The study also indicated the effect of an increase in biomass on erosion. Annual mean temperatures in Asia are expected to increase by 2–4°C, which is above the global mean increase. Together with the increased $CO_2$ concentrations in the air, this will have an effect on biomass. In areas with increased annual rainfall, biomass is expected to increase, thus protecting the soil against erosion and potentially limiting the expected increase in erosion. In areas where rainfall is expected to decrease, however, erosion may actually increase due to a reduction in biomass. The temperature increase is also expected to have an effect on mulching and organic matter content of soils, due to higher decomposition rates, resulting in less protection of the soil.

Climate change is thus expected to significantly increase water erosion in most parts of

Asia. This will be especially significant in countries that are already facing high levels (more than 10 per cent of their land area) of moderate to severe water erosion, such as Bangladesh, India, Pakistan, Philippines and Thailand. Mean annual precipitation in all these countries is expected to increase, with the main increase expected to come from more intensive precipitation. But also in countries where erosion is currently mostly light or negligible, the expected increase in erosion of around 20 per cent may result in erosion levels becoming moderate or even strong to extreme in many areas.

Wind erosion will increase in areas where the mean annual rainfall is expected to decrease. This is mainly central Asia, where the decrease in annual precipitation is likely to be accompanied by an increase in frequency of very dry spring, summer and autumn seasons. But also in other regions, wind erosion can be expected to increase because the increase in precipitation during the rainy season is expected to be accompanied by a decrease in precipitation during the dry season. This will mainly be relevant in those countries that are already severely affected by wind erosion, namely China, India and Pakistan. In China, wind erosion already buries 210,000 hectares of productive land annually and this is increasing, with the frequency of strong sandstorms having gone from 5–8 annually in the 1950s and 1960s to 14–20 per year in the 1980s and 1990s.[7]

Climate change will also result in water availability becoming negatively affected. Although mean annual precipitation is expected to increase in most regions, this will generally be due to more intensive precipitation events. As a result, the portion of precipitation lost as runoff is likely to increase, with the overall volume infiltrating the soil and becoming available to the crop because soil moisture or groundwater expected to become less.

At the same time, drought periods are expected to become more severe and longer in duration in all regions in Asia, making rainfed crop production more dependent on moisture stored in the soil and groundwater. Increasing temperatures will also result in higher water demands by the crops, leading to even higher water stress.

The expected decrease in soil moisture availability and the foreseen increase in soil moisture dependency for rainfed agriculture will therefore result in a greater need for increasing water availability and storage by limiting runoff. Especially in Central Asia where precipitation is expected to decrease as well as become more focused in intensive rainstorms during the winter season, the conservation and storage of water will be required to ensure sufficient water during the growing season. But also in other areas where drought risks are expected to increase, storage of water in surface reservoirs or

7 ADB: *Building climate resilience in the agriculture sector in Asia and the Pacific* (Manila, 2009).

groundwater aquifers will make it possible to provide supplementary irrigation to crops when required.

## 5.3 Adaptation to climate change through soil and water conservation

To avoid a decrease in crop yields as a result of climate change, soil and water conservation measures will be required. Soil conservation measures aim to reduce erosion by water and wind, reducing loss of topsoil and loss of arable land due to terrain deformation, while water conservation measures aim to increase water infiltration and storage, making it available to the crop and for personal consumption.

Soil and water conservation measures will also have important off-site effects. A decrease in erosion will result in a lower sediment load in runoff water, reducing the siltation of reservoirs and irrigation systems, which would otherwise further increase the water stress resulting from climate change as well as the sedimentation of rivers that may lead to increased flooding. The reduction and retention of runoff upstream will further reduce the risk of flooding downstream. Runoff and erosion control will also reduce the pollution of water sources by chemicals and nutrients carried with the water and sediment.

Although the objectives of soil conservation and water conservation are slightly different, the required measures are very much the same and are aimed at reducing and slowing down runoff, or redirecting it. Some of the soil and water conservation measures also result in a decrease of wind erosion. The measures can roughly be divided into vegetative measures, soil management measures and physical measures, although these are often combined. These will help avoid the increased loss of topsoil and nutrients through water and wind erosion as well as the loss of arable land through terrain deformation; but it will also make more water available to the crop, either directly in the root zone or indirectly through groundwater recharge and surface water storage.

The following vegetative measures aim to increase the coverage of the soil, protecting against both raindrops and wind and to slow down the flow of runoff, increasing infiltration and reducing erosion.

- Mulching refers to the covering of the soil with vegetative residue, such as straw, maize stalks or palm fronds. The mulch protects against raindrop impact and wind, reduces surface crusting and slows the flow of runoff water. Mulch also reduces the loss of soil moisture through evaporation. Generally, the remains of the previous crop are left on the field and used as mulch or are ploughed into the soil. Mulching can reduce water erosion by 25–90 per cent. Mulching also helps against wind erosion by forming a barrier between the wind and the soil.

- Vegetative cover refers to the planting of vegetation to protect the soil against erosion in areas where there is no or insufficient vegetation. This is often done for slopes along roads or in degraded areas to avoid off-site damage. Quick-growing plants with strong root systems are often used, such as vetiver grass. An evenly distributed cover of 40 per cent of the soil surface can already reduce erosion by as much as 90 per cent compared to bare land.

- Strip cropping is used in agricultural fields where protective vegetative cover would compete for moisture and nutrients with the agricultural crop. Here, such protective vegetation is planted at regular intervals to slow down runoff flows. For water erosion and conservation, vegetative strips are generally planted along the contour lines, perpendicular to the water flow, usually with no tillage in the vegetative strips. Close-growing vegetation is used that is thick and near the ground, slowing down runoff water and trapping sediment. The location of the vegetative strip may be rotated each year as a sort of fallow system. Such vegetative strips are easy and cheap to establish and maintain and are very effective in 6–15 per cent slopes. Strip cropping can reduce erosion by 75 per cent.

- Alley cropping refers to a kind of strip cropping in which narrow strips are planted with shrubs and trees to increase the effectiveness and stability, although this will make the strip more permanent. Regular pruning of the trees is required, which may increase labour requirements. The trees are generally nitrogen trapping or fruit producing, and prunings may be used as green manure, mulch or fodder.

- Windbreaks are used in the case of wind erosion as vegetative barriers placed perpendicular to the predominant wind direction. Although low vegetation may also be effective in trapping sediment transported by wind creep, generally trees are used to reduce wind speeds above the soil. These barriers should allow some wind to pass to avoid eddies, which can in fact increase wind erosion. The windbreaks can provide protection for approximately 20 times their height.

The following soil management measures aim to improve the characteristics of the soil and reduce its susceptibility to erosion through improvement of the soil structure and by appropriate tillage methods.

- Soil improvement refers to the increase of the organic matter content and the management of the soil to create larger soil aggregates. Although the soil composition cannot easily be changed, leaving the crop residues on the field and adding organic material can improve the soil. The increased organic matter reduces susceptibility to erosion and crusting and improves infiltration. Appropriate timing and choice of tillage operations can also increase the soil aggregate size, making them less susceptible to erosion. This also increases micro relief and water storage, reducing runoff.

- Subsoiling is specifically aimed at breaking open the compacted layer that develops below the ploughing depth, thus increasing the infiltration and water storage. It is generally carried out before the rainy season.

- Ripping is the breaking open of the soil at regular intervals without inversion.

The seeds are planted in the ripped slots while the undisturbed area can act as a catchment area, resulting in more water for the plants and is also less susceptible to erosion. Ripping is a lighter operation, requiring less pulling power and allowing tillage to be carried out before the rains, which allows the growing season to start with the first rains.

- Rainwater harvesting refers to the collection of runoff water from a catchment area and its use in a cultivated area. In the case of in situ rainwater harvesting, soil management practices are used to stimulate runoff directly above the planted crop while around the crop, infiltration is increased, resulting in more water becoming available to the root zone of the crop.

- Minimum tillage refers to the approach where the disturbance of the soil is minimized to the opening of a narrow slot for seed planting. The remaining soil is left undisturbed, with plant residue on top. Infiltration is high because macro pores are not disturbed by ploughing, although it may initially decrease in land that was ploughed before. Minimum tillage can reduce erosion by up to 75 per cent.

- Contour tillage and ridging is the approach in which the land is ploughed along the contour lines. The resulting furrows act as small dams blocking the flow of water down the slope, and encouraging infiltration. Where soil aggregates are stable, contour tillage can reduce erosion for the full growing season. For some crops that are grown in ridges, tied ridges are sometimes applied to further reduce water flow and promote infiltration. Contour tillage can reduce erosion by 50 per cent. Such ridging and furrow formation also assists against wind erosion by trapping the larger soil aggregates affected by creep.

The following physical measures basically aim to reduce the slope gradient and slope length, as well as physically stopping or slowing down the runoff flow and redirecting it where necessary. Physical measures tend to be more costly and require more time to give benefits. They are generally used in steeper areas and areas that are more prone to erosion or already degraded, as well as to protect downstream areas and infrastructure.

- Contour banks are earthen banks laid along the contour. Sometimes they are vegetated to improve their strength and to make the area productive for the farmer. The objective is to stop the runoff flow and to increase infiltration. They reduce the slope length and are very effective in larger fields but can prove problematic to implement where fields are small and fragmented.

In areas with more rainfall, contour banks may also serve to guide the water to a natural or artificial waterway where it can flow safely down the slope. They must be properly laid out with a horizontal or minimal uniform slope to avoid concentration of water in low parts and subsequent breakthroughs. The banks can alternatively be made from rocks and stones, which results in stronger and porous banks that have less risk of breakthroughs. In areas with less rainfall, the water may be kept in place by so-called teeth perpendicular to the contour bank up the slope, which stop the flow of water along the bank and increase infiltration. These may also be combined with trenches to allow greater water storage. Due to soil sedimentation behind the banks, bench terraces can develop with time, further reducing erosion by decreasing the slope gradient.

- Contour trenches are used on steeper slopes where contour banks are more susceptible to breakthroughs. Instead of banks, trenches are dug to catch the water and sediment and allow it to infiltrate. It is recommended to use staggered or tied trenches to avoid water flowing through the trenches and possibly resulting in serious damage due to the concentration of water.

- Terraces are formed to convert steep slopes into a series of steps with (nearly) horizontal ledges and almost vertical drops. They may be formed gradually as bench terraces by sedimentation behind contour banks or vegetative barriers but can also be constructed using cut and fill. The vertical drops are often reinforced with vegetation or stones. Terraces are very common in upland rice cultivation where horizontal fields are required.

- Diversion ditches and waterways serve to guide excess water safely away from the field, effectively decreasing the slope length of the field and reducing the runoff volume. The diversion drains are placed at the top of the field as catch drains or along the slope at regular intervals to collect runoff water and guide it to a natural or artificial waterway. Diversion drains are often combined with contour banks and are at a slight angle to the contour to allow easy drainage. The waterways go down the slope and are generally grassed or lined with stone or even concrete to protect them against erosion. Such waterways may be linked to surface storage facilities, such as dams or ponds.

- Check dams are constructed in waterways or gullies to slow down the water flow. They are generally porous to avoid the need for very strong structures. Small check dams may be made of bamboo, timber or loose rocks. Larger structures are typically made of gabions or stone masonry with weep holes. The slowing down of the water flow causes sediment deposition behind the check dam, which, with time, results in steps being formed. Check dams can thus be used to stabilize eroding gullies, making the land productive again. The check dam should have a dip in the middle to avoid water flowing around the sides and causing damage. For larger check dams, an apron may be needed in front of the check dam to protect against erosion by the falling water that can undermine the structure.

- Small dams are used in water conservation, in which water in a water course is stored behind a dam. They can also be used as a form of off-site water harvesting, where runoff from a rocky or mountainous area is guided to the dam. Care must be taken in the construction of the dam to avoid breakthroughs that may cause serious damage and flooding downstream. The dams may be earthen dams or made of stone masonry or concrete. The location of the dam depends on the topography in the sense that the smallest dam size results in the largest water storage volume. The water in these dams may be used for gravity irrigation further downstream.

- Percolation ponds are natural or excavated depressions in which water from a catchment area is collected and stored for later use. Water is guided to the pond by the natural topography or through canals. Percolation ponds are very common in India and southern Nepal and are used for drinking water, fishing, washing and irrigation. The water is also used to recharge groundwater. The diversion ditches and waterways mentioned here can also be directed to such ponds. Because these ponds are generally in low areas, they are not very suitable for gravity-fed irrigation, and pumps will be required.

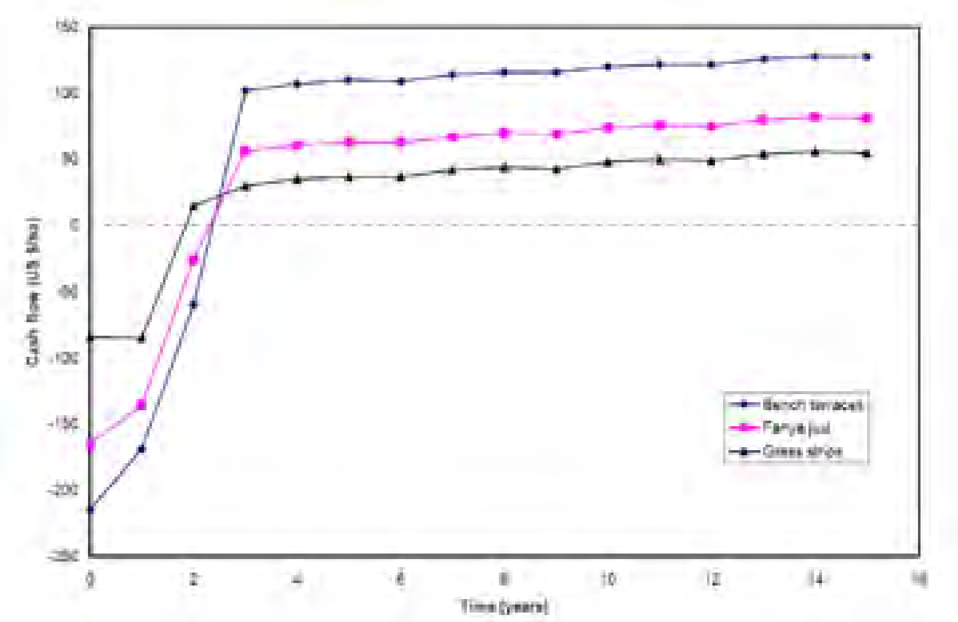
- Subsurface dams are used to stop the flow of groundwater and make it available for a longer period. They are built to a depth where an impermeable layer exists, thus avoiding water flowing underneath the dam. They are often made of concrete or stone masonry, although clay with plastic sheets is also used. The subsurface dams are often combined with check dams to further improve water retention.

- Riverbank protection generally consists of providing a protective layer to the riverbank in the form of gabion walls or loose rocks. In some cases, woven twigs or bamboo are used instead of gabion mesh. Another option is the slowing of the water flow near the bank, usually achieved by means of gabion or loose rock walls protruding into the river. Care must be taken not to slow the flow so much that it results in the river level increasing and causing flooding.

Of the three types of measures mentioned above, vegetative and soil management tend to be the cheapest to implement (figure 5.2), with low skill requirements and more immediate returns to the investments made. Mulching, strip cropping, minimum tillage and contour tillage have proven to be inexpensive with rapid productivity increases, leading to higher adoption levels by farmers. They are applied at the field level and therefore have low organizational requirements because agreements with neighbouring farmers are generally not required. Documented experience with these measures already exists within the different regions and can easily be built upon and improved.

However, with the increase in high intensity precipitation events and increased runoff volumes, these measures are likely to prove insufficient to significantly reduce water erosion in many areas. Such areas with high rainfall will therefore also require other intervention measures, such as contour banks, which may be combined with diversion ditches and waterways to ensure the safe guidance of runoff water away from the field and down the slope.

Figure 5.2: Example cash flow for three soil and water conservation measures




Source: EROAHI: *Tools for catchment level soil and water conservation planning in the East African Highlands* (2005).

These contour banks, diversion ditches and waterways are ideally linked to surface water storage or groundwater recharge for use in drought periods or the dry season. This can be achieved through the construction of dams and check dams in the waterway, or by building percolation ponds and guiding the runoff water there. Such groundwater recharge and surface water storage can then serve for household use as well as supplementary irrigation during drought periods. These can be storage units at farm level, but may also cover a larger area and serve several farms and households.

Gully erosion will also become more significant due to climate change, with increased runoff volumes. The construction of check dams will help stabilize such gullies as well as provide water storage and groundwater recharge. In the case of riverbank protection, high water flows will increase due to more and more intensive rains (the maximum monthly flow of the Mekong, for instance, is expected to increase by as much as 40 per cent[8]). More and stronger river protection works will therefore be required to protect against the loss of arable land and against damage to infrastructure, creating loose stone layers or gabion walls at sensitive points.

The role of vegetative and soil management measures for soil and water conservation will therefore become of greater importance with climate change, as a means to combat the greater runoff intensities and avoid the loss of soil productivity and arable

8 ADB: *Building climate resilience in the agriculture sector in Asia and the Pacific* (Manila, 2009).

land, as well as to achieve greater water retention for use by the crop. However, the increased rainfall intensities will mean that vegetative and soil management measures will become insufficient and that the need for physical structures will increase. These will aim to effectively stop the flow of water down the field and to guide any excess water safely down the slope, storing it for future use where possible.

With 167 million hectares in Asia affected by moderate to extreme water erosion and another 108 million hectares affected by moderate to extreme wind erosion, there is already a strong need for soil conservation measures, and that will only increase further as a result of climate change. The expected decrease in water availability will furthermore require water conservation measures, especially in those areas where annual rainfall is expected to decrease or where extended drought periods are foreseen. This implies a huge task in implementing these measures, even when only concentrating on those areas that are most severely affected by climate change.

The vegetative and soil management practices are easily applied at the farm level and generally do not require much support from governments other than awareness raising and training, together with certain incentives. The physical measures, however, require larger financial and technical inputs and as such will generally need external support. These measures are also often applied in communal and public lands. The involvement of local governments in such works will be necessary, both to provide the technical expertise and financial support and to assist in the organization of local communities.

***Soil and water conservation in India's rural employment scheme***

*Projects implemented under the National Rural Employment Guarantee Act (NREGA) in India include many soil and water conservation activities. In the 2009–2010 financial year, nearly one million water conservation and harvesting subprojects were executed. After rural roads, this is the single greatest sector in terms of expenditure. Over 50 billion Indian rupees (approximately US$1.25 billion) were spent on water conservation and water harvesting in that year, representing nearly a quarter of the total expenditure on works. These works also form an important opportunity for employment creation, with 70 per cent of the investment spent on labour wages, resulting in the creation of over 600 million workdays, or nearly 40 per cent of the total employment created under NREGA in that year.*

## 5.4 A local resource-based approach to soil and water conservation adaptation and expansion

The greater need for soil and water conservation measures, including physical structures, presents an ideal opportunity for promoting the use of local resources in their implementation. This offers the opportunity for creating employment and developing skills, as well as reducing erosion and ensuring greater water availability. This section discusses how the use of such local resources can and have been used effectively and will produce better results in cost-effectiveness, maintenance and sustainability. Many of the measures described in the previous section are also, by nature, employment intensive because their design and location generally make the use of equipment uneconomical or even impossible.

## Local participation and planning

Although soil conservation measures have existed as long as agriculture itself, the introduction of new soil conservation measures has not always been a success. This was often because their introduction was "top-down" and often focused on physical structures intended to reduce sedimentation and flooding-related problems downstream. These were often promoted by making their application compulsory or by paying for their construction. The former led to a high resistance to soil conservation measures, while the latter led to lack of maintenance or even destruction once payments ended.

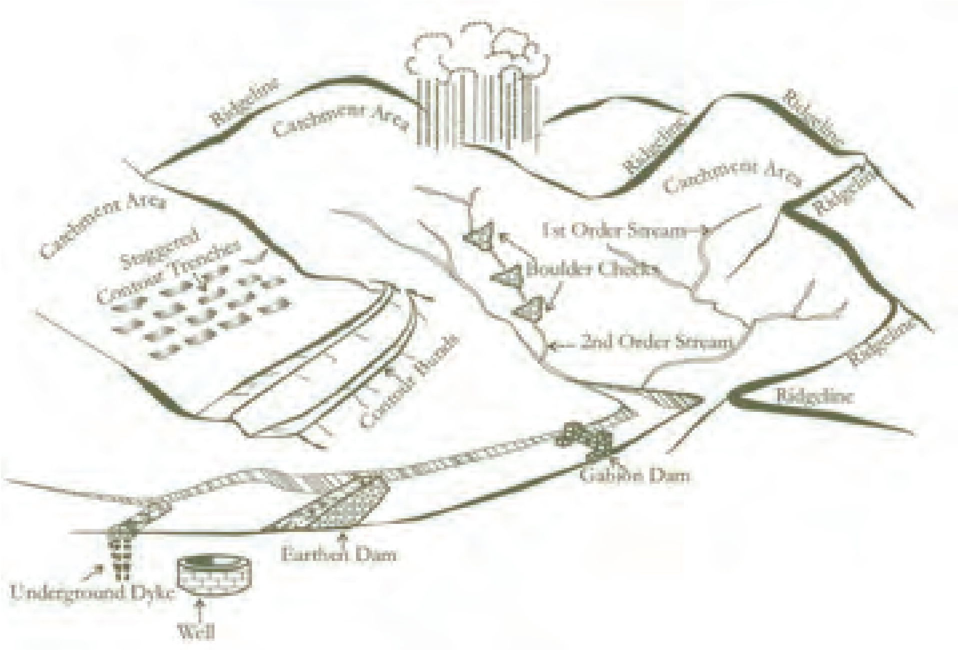
The farmers in whose land the structures were built saw no obvious benefits in terms of solving their immediate needs. Later experience with the introduction of vegetative and soil management measures focused more on productivity improvement and were much less costly to implement. This led to far greater acceptance by farmers who saw immediate short-term benefits for themselves.

The introduction of water conservation measures also has been more successful due to the perceived direct and short-term benefit to the farmers and communities. Increasing the availability of water on-site was seen as the main objective, and the decreased risk of flooding downstream was seen more as a secondary benefit.

This leads to the conclusion that the introduction of soil and water conservation measures should focus on the benefits for those that have to implement and maintain them and should ensure a participatory approach that results in the acceptance of the proposed measures in order to ensure greater sustainability. Unless local people are convinced of the benefits of such measures, it is unlikely that their introduction will be successful in the long run.

In terms of participatory planning in soil conservation, watershed management became popular in the 1990s. A watershed or hydrological catchment is a geographic area where, as a result of the existing topography, all precipitation falling within its boundaries drains to a single outlet. It is therefore the ideal unit for soil and water conservation planning. Figure 5.3 illustrates a watershed management plan.

Figure 5.3: Watershed management plan




Source: NREGA: *Watershed works manual: An introduction to social and institutional issues in watershed development* (New Delhi, Government of India, 2006).

The basic concept was that the downstream and the upstream populations would enter into dialogue about water use and erosion control. This included possible payment by downstream populations to upstream farmers to carry out conservation works intended to reduce flooding and sedimentation downstream, especially in cities. Initially, this was not very successful because it was applied in very large watersheds, making the distance between and the number of different stakeholders too large. The linkage between major flooding downstream and one farmer's land management was, inevitably, unclear.

Watershed management was later applied in smaller watersheds or micro catchments, where it proved much more successful. Priority micro catchments are identified within a greater watershed, generally using Geographic Information Systems and Remote Sensing, and detailed planning is carried out only in these micro catchments. The focus was also shifted more towards direct benefits for all, looking especially at productivity gains and water availability for upstream farmers rather than seeing soil and water conservation only as a means of limiting problems and damage for downstream populations and cities.

One problem that is still faced in the watershed management approach is that the planning area is based on topographical boundaries of hydrological units, while decision-making and public investments are based on administrative boundaries. This often complicates the execution of proper watershed management plans and forces SWC planners to consider areas that do not follow catchment boundaries, despite the disadvantage of losing the hydrological linkage between different farms.

Although genuine local acceptance of the benefits of soil and water conservation measures is required for long-term sustainability, initial introduction of such measures may be promoted through the use of incentives and pilots. The incentives should be longer term, however, and not just payments during construction because experience has shown this does not work.[9] Longer-term incentives may include tax benefits, subsidies, loans, inclusion in beneficial government programmes, etc. Land tenure security is also very important in the success of soil and water conservation measures, as people will be less willing to invest time and money in land to which they have no secure usage rights. In the end, the most important requirement for the successful introduction of soil and water conservation measures is the motivation of farmers and communities who are convinced of the short- and long-term benefits to be obtained.

Participatory planning for soil and water conservation necessarily needs an area-based approach, with the catchment as the focus area. Problems can be identified through community mapping with representatives from different parts of the community and areas of the catchment. Such problems may include loss of topsoil, lack of nutrients, low yields, insufficient water availability, gully formation, riverbank erosion, landslides, damage to infrastructure, etc. These mapping exercises are best done on the ground using local materials. Large sheets of paper with different colour markers can also be used. It is important to ensure the participation of all social groups in this process, as not all community members will experience the same problems.

The problem identification is then followed by discussion of possible remedial measures. The input from local government technicians or extension workers can be important here to introduce a range of possible measures and to explain the costs and benefits of each. It is recommended to first pilot some of the measures to let farmers and community members become familiar with them and to allow them to make an informed choice for certain measures, ensuring greater sustainability. This may also be achieved through exchange visits to other catchments.

Vegetative and soil management measures are generally carried out in individual fields and will only require basic training of motivated farmers. The required financial inputs are small and often can be provided by farmers, although incentives such as interest-free loans can help in the adoption. In the case of physical measures in which the required technical and financial inputs are greater and which often also go beyond the

9 The provision of payments for the creation of soil and water conservation measures without longer-term incentives, for instance, has often lead to such measures being neglected or even destroyed after the payments have ended.

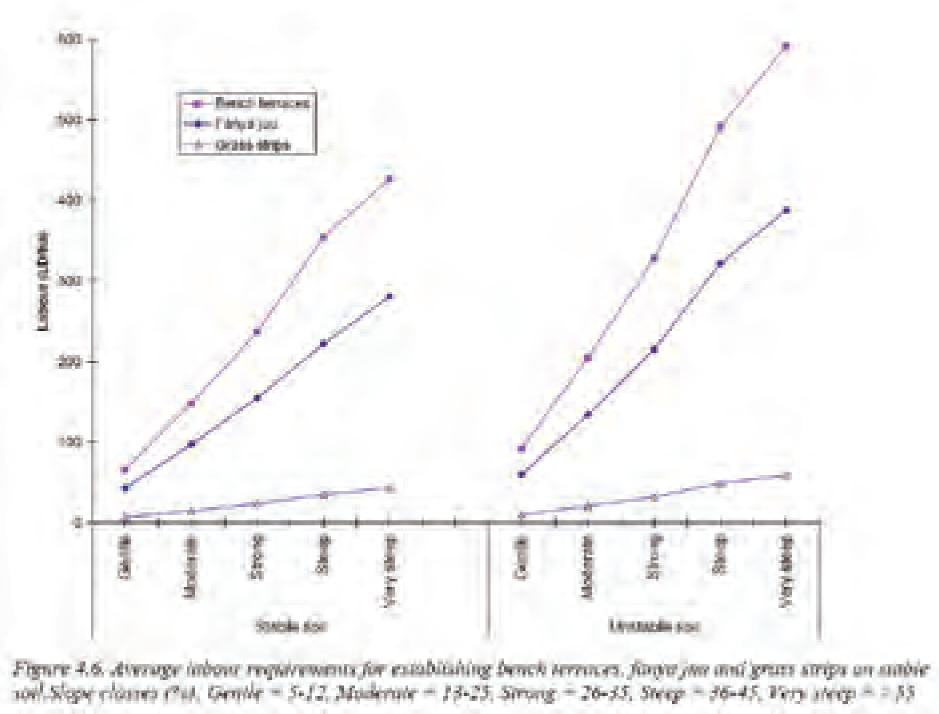
individual farm or are implemented on communal or public land, significant external support will be required for their success. This will include organizational support in motivating community members but also technical support in designing and positioning of structures as well as financial support.

## Technology

The technology used in soil and water conservation was to a certain extent described in general terms in the previous section. This section focuses on the physical soil and water conservation measures that tend to go beyond the level of one single field or are applied on communal or public land, which require significant inputs and are more permanent in nature. For these measures, we identify the possibilities for using local resources with the aim of creating employment and income as well as ensuring greater levels of adoption and sustainability. This section does not look in detail at vegetative and soil management measures carried out at the field level; they can easily be carried out by a farmer and his or her family and tend to be repeated every growing season. Mulching or ripping, for instance, will be repeated each growing season.

The implementation of soil and water conservation measures tends to be very labour intensive, with labour costs easily forming 70 per cent of total costs. The use of equipment is generally less suitable, due to the nature of the work and the location where they are carried out, making equipment less economical or outright impossible. The labour inputs are especially high for physical measures, although they also tend to be high in the case of planting vegetative cover on steep or degraded slopes. Figure 5.4 gives an indication of the required input per hectare for three very common types of measures.

Figure 5.4: Average labour requirements for establishing soil and water conservation measures



Source: EROAHI: *Tools for catchment level soil and water conservation planning in the East African Highlands* (Wageningen,2005).

One vegetative measure that is widely applied in public land and with a longer-term view, often to protect underlying areas and infrastructure against flooding, sedimentation and landslides, is vegetation planting (this is also often referred to as bio-engineering). This may involve the planting of sturdy grasses but can also involve shrubs or even reforestation (the latter is described in greater detail in chapter 8). Vegetation planting is often carried out in the protection of roads, applying it to slopes above and below the road. It may also be applied in steep or degraded communal or public lands where vegetation has been lost due to overgrazing. The plants may be very specific erosion-combating plants that are obtained from nurseries but can also include local varieties that are obtained from nearby areas. The plants should be close growing with strong root systems and ideally should have additional benefits, such as use for fodder or green manure. Vegetation planting tends to require high levels of (unskilled) labour for the planting and sometimes also for cutting and pruning, as well as for the nursery. One person may plant 50–250 plants per workday (depending on the slope gradient and soil type), and labour inputs per hectare tend to range from 250 to 500 workdays, including nursery work and plant maintenance.[10]

10 ILO: *Productivity norms for labour-based construction* (Geneva, 1998).

Although contour banks and contour trenches can be applied at the field level, where fields are small and fragmented they usually cover several fields, especially where they also serve to guide water away from the field to waterways. Their construction is relatively simple and is generally limited to earthwork, although they may also involve the use of stones and rocks. The required skill level is also low, making the work suitable for unskilled labour with some very basic training and supervision (especially regarding the measuring of contours – see the next section for more details). Labour inputs range from 50 workdays per hectares for gentle slopes to 300 workdays per hectares for steep slopes, mainly as a result of the banks being placed closer together.

Contour trenches are generally used in steeper areas, often involving communal or public land. Terraces are not often built, directly due to the high costs involved and are generally formed through the catchment of sediment behind vegetated contour banks, leading to the formation of bench terraces. Where such terraces are built all at the same time, labour inputs can become as high as 600 workdays per hectares for steep slopes.

Diversion ditches also involve simple earthwork, including the excavation of a ditch and the formation of an earthen bank on the downhill side. Where artificial waterways are created to guide the water downhill, they will need to be protected against erosion. Although stone masonry or even concrete is sometimes used for the lining of particularly steep waterways, this is generally only done to protect roads and other infrastructure. For agricultural land, the waterways are usually grassed to protect them against erosion, and, in some cases, simple stone facing is used. Both grass planting and stone facing make use of local materials and can be carried out by unskilled labour. Labour output for stone facing varies from 10–15 square metres per workday, depending on the stone type and layer thickness.[11]

Check dams are also often applied in waterways to slow down the water flow and reduce the risk of erosion. Such check dams are also used in gully control and may be built of timber or bamboo, loose rocks, gabions, stone masonry or in extreme cases even concrete. Generally, use will be made of local materials and labour. Supervision will be required for the proper location of the check dams, while for larger check dams, proper designs will also be required. Stone masonry and concrete dams will need some skilled labour, while gabion, dry stone and timber check dams can be built by unskilled labour with minimal supervision.

Small dams tend to be made of earth with a clay centre, although stone masonry and concrete dams are also quite common. Subsurface dams tend to be made with plastic

11 ILO: *Soil conservation: Project design and implementation using labour intensive techniques* (Geneva, 1988).

sheeting, stone masonry or concrete. Apart from cement, reinforcement bars and plastic sheeting, the materials are generally locally available. Skilled personnel will be required for the proper design, positioning and construction of the dam to ensure its proper functioning, and for stone masonry and concrete dams, some skilled labour will also be required, but most of the required labour will be unskilled.

Percolation ponds are basically excavated depressions in the land. This involves soil excavation and subsequent transportation away from the pond. Materials are generally not required, and all works can be done by local labour. Especially where the location of the pond is remote or difficult to reach, the use of heavy machinery will not be viable. The excavation of percolation ponds allows for high levels of employment generation and is easy to manage, with many benefits for local communities in terms of year-round water availability, making it a favourite, with high community priority in programmes such as NREGA in India.

River protection measures are mostly made using gabions or simple rock facing along the river edge. In other cases, woven twigs or bamboo may be used. The rocks are generally obtained locally, although some transport may be involved. With some basic training, the placing and filling of gabions can be carried out by unskilled workers.

Most soil and water conservation measures described in this chapter are extremely suitable to implementation using local resources. Most of the work involves soil excavation, and any materials used are generally locally available. Other materials that

might be required involve mainly cement, reinforcement steel and plastic sheeting, which are easily obtained, often locally. Unskilled labour can be used for almost all activities and is commonly the only option because access by heavy equipment is difficult and not economically viable. Some skilled labour will be required for stone masonry and concrete works as well as for the designing and positioning of certain larger structures.

## Organization of labour inputs

An important aspect in the planning and implementation of soil and water conservation works using local labour is the estimation of the amount of labour required and its organization. In such labour-based works, task-based remuneration systems are generally applied, whereby each individual or group of individuals is given a certain amount of work to complete, based on which the payment is made.

Such task-based systems are extremely useful in soil and water conservation works where soil excavation and transport of soil or other materials form the main type of activity. This allows for easy planning because the relation between the amount of work and its cost is known beforehand. It also allows for easy monitoring of the labour because only the completed work needs to be approved. For the workers, it has the advantage that they are able to plan their work, working harder and finishing earlier or working more slowly and finishing later.

In determining appropriate tasks and suitable remuneration levels, productivity rates are used. These define for different activities the amount of work that can be completed by one person in one workday, for instance the number of cubic metres one person can excavate. These productivity rates are defined for different types of activities, different types of soils (hard or soft), different excavation depths and different transport distances. By dividing the amount of work of a specific task by the productivity rate and multiplying it by the daily wage rate, a suitable remuneration for the task can be calculated. Tasks may consist of one day's work for one individual or several days of work for a group of workers.

**Formula for calculating a task payment based on productivity rates**

$$\frac{\text{Size of task (units) x daily wage rate (payment/workday)}}{\text{Productivity rate (units/workday)}} = \text{Task payment}$$ [12]

Examples of productivity rates can be found in the ILO Productivity Norms for Labour-based Construction,[13] although they are more aimed at road works. A very useful document is the ILO *Soil Conservation*,[14] which explains in detail the process for designing and implementing soil conservation measures, including the required labour and material inputs. NREGA has included a number of productivity rates for soil and water conservation works in its Watershed Works Manual.[15] For earthworks, the most common activity in soil and water conservation, the productivity rates used by NREGA are given here. It is recommended to always evaluate the appropriateness of productivity rates when applying them in other areas. Where suitable productivity rates are not readily available, these may be calculated by first applying a well-monitored time-based approach, paying workers on a daily basis and measuring their productivity for different activities. For certain activities, task rates are not very suitable, and time-based or input-based remuneration systems may be used.

Table 5.6: Productivity rates for soil excavation in cubic metres per workday

| Soil type | Transport distance: less than 25 m | 25-50 m | 50-75 m |
|---|---|---|---|
| Loose soft soil | 2.50 | 2.42 | 2.35 |
| Kankar/mooram soil | 2.30 | 2.18 | 2.11 |
| Mooram, laterite, boulder | 1.90 | 1.89 | 1.78 |
| Soft rock requiring blasting | 0.80 | 0.75 | 0.73 |
| Hard rock | 0.30 | 0.24 | 0.23 |

Source: NREGA: *Watershed works manual: An introduction to social and institutional issues in watershed development* (New Delhi, Government of India, 2006).

## Capacity building and contracting

Required skill levels for soil and water conservation works are generally low, making the use of unskilled local labour possible. Nevertheless, capacity building will be required at different levels, including farmers and community members, local contractors and local authorities.

For on-farm vegetative and soil management measures, as well as for a number of physical measures, one important skill required is the ability to set out contour

12 For the task of excavating 20 cubic metres of Mooram soil and transport of the excavated material over an average distance of 10 metres, with a productivity rate of 2.3 cubic metres per workday and a daily wage of 68 rupees per workday this would mean (20 cubic metres x 68 rupees per workday) / (2.3 cubic metres per workday) = 590 rupees).

13 ILO: *Productivity norms for labour-based construction* (Geneva, 1998).

14 ILO: *Soil conservation: Project design and implementation using labour intensive techniques* (Geneva, 1988).

15 National Rural Employment Guarantee Act (NREGA): *Watershed works manual: An introduction to social and institutional issues in watershed development* (New Delhi, Government of India, 2006).

lines along which to carry out the different measures (contour tillage, grass strips and vegetative barriers, contour banks, contour trenches). Although for contour tillage and grass strips, it is acceptable if they are not exactly according to the contour; for contour banks that catch higher runoff volumes, deviations from the contour line can result in serious damage due to the concentration of water. Sometimes the contour banks and diversion ditches are set at a slight angle to the contour to guide water away from the field, in which case it is important to ensure the angle is uniform and not too great.

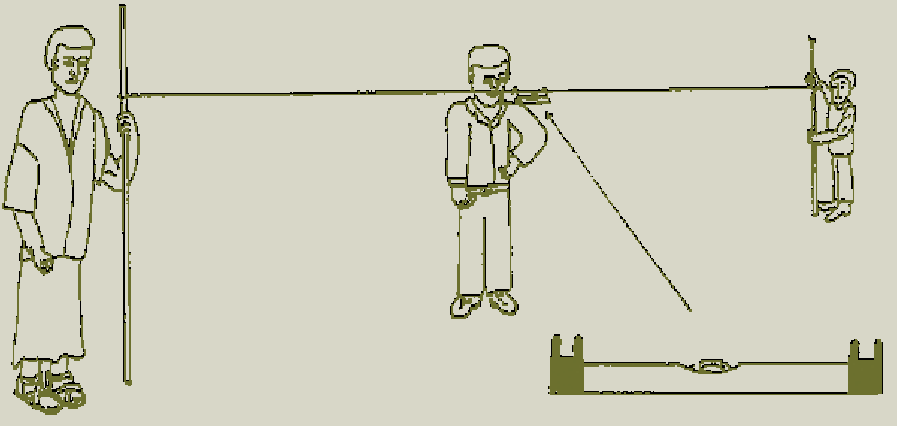
The setting out of contour lines is not very difficult and can be carried out using simple tools and minimal training. Generally, the aim is to identify different points in a field that are at the same level, although for certain activities the identification of a uniform slope may be required. Only in the case of (check) dams and ponds will it be necessary to measure height differences. Most of these measurements can be carried out by local labour after a short initial training.

Apart from the measuring of contour levels, slopes and height differences, skills will be required for stone masonry and concrete construction works involved in larger physical structures. Experience with such works generally exists with local contractors, although some additional training may be required to ensure the proper quality of work. For structures made from gabions or loose stones (including dry stone masonry), local contractors may be used, but unskilled labour can also easily be trained to do this properly.

***Simple measuring devices***

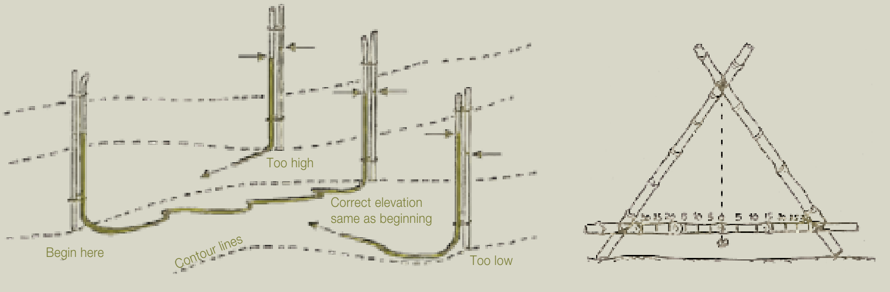
*Although the dumpy level and theodolite are the most versatile height-measuring instruments, they are often not readily available and require significant training for them to be used properly and effectively. A hand level is easier to use and can be used for both the measurement of contours and height differences and even for slope calculations; however, it is not always available locally.*

*An N-frame or line level both make use of simple levels attached respectively to an N-shaped wooden frame or to a string between two poles. These are relatively easy to use and the required materials are generally locally available, with levels being available in most hardware stores. Both can be used for measuring contour levels as well as uniform slopes but are not suitable for measuring height differences. The N-frame has the advantage that it only requires one person to use it as opposed to three for the line level, but the line level can cover greater distances with each measurement.*



N-frame and line level– Source: FAO

*The tube level only requires a transparent tube and two poles. It can be used for measuring contour lines and height differences and if combined with distance measurements, also for uniform slopes. The tube is a bit costly and susceptible to damage, but as a whole it is easy to use by two persons. The simplest measuring device is the A-frame, which can wholly be built from local materials and is very easy to calibrate and use by one person. Its accuracy is a bit lower but acceptable for most soil and water conservation measures.*




Tube level and A-frame – Source: NREGA

***Riverbank protection in Nepal***

*The ILO EMPLED project in Nepal also included riverbank protection to safeguard arable land from flooding and damage. A protective dyke was built that was protected by grass and gabions. The works were carried out by community organizations, with minimal technical training.*



The design and location of physical structures, such as check dams and dams, will require competent technical personnel. Local authorities or hired consultants, both of whom may require additional training, can generally do this. Skilled labour, supervised by the technical personnel, will be required during the construction process. The Watershed Works Manual of NREGA[16] and the Soil Conservation guide of the ILO[17] contain basic design and measuring guidelines for the preparation and implementation of physical soil and water conservation works.

Once the location and design of the soil and water conservation works have been set, the implementation of works can either be contracted out to a contractor if works require technical expertise or to local communities or beneficiary groups. The latter allows greater skills development and can be very successful where required skill levels are not very high. In this case, the funds are managed by the beneficiary or community group, which is responsible for the hiring of labour, the purchase or collection of materials and the construction of works. This generally results in higher levels of appropriation of the works and, together with the obtained skill levels, leads to better maintenance and greater sustainability. Suitable arrangements for such community contracting can be found with the ILO and the World Bank (where it is referred to as "community-driven development").

## Maintenance and sustainability

The maintenance and sustainability of soil and water conservation measures will depend on the degree of acceptance by farmers and communities and their perception of the benefits, especially in terms of productivity and water availability. Community participation in planning and implementation is essential to ensure proper adoption and avoid the physical measures being left without maintenance or even destroyed. Even where acceptance and perceived benefits are high, sustainable arrangements for

16 NREGA: *Watershed works manual: An introduction to social and institutional issues in watershed development* (New Delhi, Government of India, 2006).

17 ILO: *Soil conservation: Project design and implementation using labour intensive techniques* (Geneva, 1988).

maintenance will be needed. This is especially true where measures are implemented that cover several fields or that are situated on communal or public land. With vegetative and soil management measures at individual field level, maintenance will be the responsibility of the owner or user of that land who will benefit from proper care. In other cases, the beneficiaries and responsibility for maintenance are not always clear.

Future maintenance needs must be just as much a part of the planning stage as the location, nature and construction of the physical measures. A clear distinction is necessary between agreeing who is responsible for maintenance and agreeing what maintenance will be needed. If it is a small group, members can agree to carry out the maintenance together in certain periods of the year, making clear what the input of each person will be. Where the beneficiary groups are larger and more scattered, the agreement on contributions (generally in labour or materials) will not be as easy, and it will be essential to elect a maintenance committee that will be responsible for coordinating the different inputs in cash or kind.

Cash maintenance fees can be beneficial for larger conservation measures, ensuring that all beneficiaries contribute according to the degree to which they benefit, and allowing labour to be hired and materials to be purchased according to need. In such schemes, “voluntary” contributions of labour and materials tend to be less successful. The required inputs are generally not available when most needed, and the poor, who are more dependent on the measures and have less alternatives, tend to be the ones providing most of the “voluntary” contributions.

Maintenance works can also be a source of employment and income for a small group of people. They can be hired by the maintenance committee to carry out all the required maintenance work against a fixed fee per year (performance basis) or on a needs basis (time based or task based). This ensures that skills are developed in the group over time, resulting in better quality work than when voluntary labour contributions are used.

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6

# Flood control



# Flood control

## 6.1 Flooding and climate change – an introduction

Since earliest times people have lived along flood plains. They are often ideal for farming, and they offer opportunities for fishing as well as for transport along the river. The annual flooding has helped to water and to fertilize crops and has been seen as part of the natural cycle of life. Flooding is not something new, and people have learned to live with it. If population pressure was low, the inhabitants of the flood plain moved to higher ground during abnormal flooding. Rural populations have built their houses on stilts for centuries, adapting themselves to the occasional higher-than-usual water levels.

In the river valleys and deltas of South and South-East Asia, the flood plains have been very suitable for growing rice and have encouraged the development of intensive agriculture. Many early cities also developed along riverbanks, often in the same flood plains where food was available for their growing urban populations. As a consequence, many of the major cities and concentrations of populations in Asia live in flood plains and some countries, such as Bangladesh, consist almost entirely of flood plains.

Cities such as Bangkok were built on slightly higher areas of land and protected themselves from the occasional floods by making the sites of important buildings a little higher and building flood defences. Other cities such as Phnom Penh were built on ground that was drained and made higher. All these cities and various rural areas have experienced flooding due to abnormal water levels. Flooding is a problem even for the wealthy, but the poorest suffer disproportionately.

Changes in the catchment area and to the rainfall pattern due to climate change can alter flooding patterns. Deforestation, for example, leads to greater proportion of the water running off and to its arriving at the river faster. This affects the depth and the nature of the flood flow. Computer models have been made of many catchments so that forecasts can be adjusted but such data may not be available for every small river in a developing country. Manmade changes to the environment, including roads and bridges, railways and irrigation structures, lead to changes in the flooding pattern in a particular area. Changes in the water-related infrastructure, such as dams, culverts and sluices, should be designed with the overall impact on flooding in mind, but this does not always happen.

## Return period of flooding

When designing any structure that has to deal with the effects of rainfall, it is important that the engineer knows what the flows of water are going to be. This is equally true of road drainage, river training and flood mitigation. Unfortunately, it is impossible to be absolutely certain as to what the maximum level of flow will be, and a calculation is usually made on the basis of a flow that has a certain "return period". If it is an important structure, it may be built with a return period of 100 years or more. This means that there is a 1-in-100 chance that it will be overtopped in a given year. In the case of drainage on roads in a residential area, it can be a return period of two years. The inconvenience of a small paved road flooding briefly on average every two years is very small.

The height, velocity and volume of flow in rivers at gauging stations are measured on a regular basis. Where possible, the data from 30 or more years of measurement is used as the basis for estimating future flows. Where there is sufficient data available, it is possible to provide a good estimate of the return periods of a certain flow. Where more limited data is available, an attempt is made to calculate the likely flow. These estimates are used as the basis for calculating future flows to be used in the design of flood defence and other river structures, including weirs, spillways and river training. To date, the calculations have been based on the assumption that future flows will be similar to those in the past. With climate change, however, this is no longer a valid assumption. Many of the existing structures are no longer capable of dealing with the return period flood for which they were designed. Many of the poorer areas have no formal flood protection works at all.

We know that the effects of climate change will vary in different geographical areas. While one region may experience increased droughts, others will experience greater rainfall. Even where annual rainfall is lower, the intensity of the rain that does fall may be significantly higher, leading to flash flooding. Greater variability in a given area and an increase in extreme weather events are common features of climate change, making it even harder to predict. In both cases, this can overwhelm the streams and rivers as well as drainage systems, leading to flooding.

Poverty remains endemic in much of South Asia and flooding has always been a problem there. Bangladesh, one of the poorest countries in the region, is now faced with climate change and increased flooding from both the large rivers that rise in the Himalayas and from inundation from the sea.

"Given the country's vulnerability to its impacts, climate change is now the most pressing development concern [in Bangladesh]. In the recent past, the country has experienced a rise in sea level, increased temperatures, enhanced monsoon precipitation and runoff, potentially reduced dry season precipitation, and an increase in the frequency and intensity of tropical cyclones and storm surges. These harmful climate change impacts are due to the country's vulnerable geophysical location, low deltaic floodplain, hydrological influence by erratic monsoon rainfall and changes in regional water flow patterns".[1]

In South-East Asia, extreme events like La Niña and tropical cyclones have brought heavy and intense rainfall, resulting in excessive runoff and water flows to already fragile ecosystems (fragile due to poor land use planning and unsustainable use) that cause massive flooding, landslides, severe erosion of river banks and sedimentation. Compared with 1960–1990 levels, the maximum monthly flow of the Mekong River is projected to increase between 35 per cent and 41 per cent in the basin and between 16 per cent and 19 per cent in the delta. The lower value is projected to occur between the year 2010 and 2038 and the higher value between 2070 and 2099. The minimum monthly flow, on the other hand, will fall by 17–24 per cent in the basin and by

1 ADB: *Supporting implementation of the Bangladesh Climate: Change strategy and action plan* (Dhaka, 2009).

26–29 per cent in the delta. These suggest the possibility of increased risk of flooding during wet seasons and increased water shortages in dry seasons.[2]

In Viet Nam, "extreme events" include typhoons, droughts and flooding as well as heat waves. During the past 50 years, the peak month for typhoon landfalls has shifted from August to November, and most of the storms now occur later in the year. Typhoons have also tended to move to lower latitudes.[3]

Table 6.1: Observed changes in extreme climatic events affecting flooding in developing countries in Asia

| Country | Extreme rains & floods | Cyclones |
|---|---|---|
| China | Increasing frequency of extreme rains in western and southern parts including Changjiang river, and decrease in northern regions; more floods in Changjiang river in past decade; more frequent floods in North-East China since 1990s; more intense summer rains in East China; severe flood in 1999; seven-fold increase in frequency of floods since 1950s | Number and intensity of strong cyclones increased since 1950s; 21 extreme storm surges in 1950 to 2004 of which 14 occurred during 1986 to 2004 |
| South Asia | Serious and recurrent floods in Bangladesh, Nepal and north-east states of India during 2002, 2003 and 2004; a record 944 mm of rainfall in Mumbai, India on 26 to 27 July 2005 led to loss of over 1,000 lives with loss of more than US$250 million; floods in Surat, Barmer and in Srinagar during summer monsoon season of 2006; 17 May 2003 floods in southern province of Sri Lanka were triggered by 730 mm rain | Frequency of monsoon depressions and cyclones formation in Bay of Bengal and Arabian Sea on the decline since 1970 but intensity is increasing causing severe floods in terms of damages to life and property |
| South-East Asia | Increased occurrence of extreme rains causing flash floods in Vietnam; landslides and floods in 1990 and 2004 in the Philippines, and floods in Cambodia in 2000 | On an average, 20 cyclones cross the Philippines Area of Responsibility with about 8 to 9 landfall each year; with an increase of 4.2 in the frequency of cyclones entering PAR during the period 1990 to 2003 |

Source: IPCC

Sea levels in South-East Asia are rising at an average annual rate of between 1 and 3 millimetres, which is higher than the global average.[4] In Bangladesh, average sea levels are predicted to rise by around 30 centimetres by 2050 and could make an additional 14 per cent of the country extremely vulnerable to floods. Because the poor live and depend disproportionately on marginal lands, they are the most vulnerable to these impacts.[5]

The Pacific Islands are a particular problem. Those countries that are mountainous or hilly, such as Samoa and Fiji, face problems similar in the rest of the region. But those that consist entirely of low-lying atolls, such as Kiribati and Tuvalu, face oblivion as

2 ADB: *The Economics of Climate Change in Southeast Asia: A Regional Review* (Manila, April 2009).

3 ibid.

4 ADB: *The Economics of Climate Change in Southeast Asia: A Regional Review* (Manila, April 2009).

5 ADB: *Supporting implementation of the Bangladesh climate: Change Strategy and Action Plan* (Dhaka, 2009)

a result of rising sea levels. These are some of the poorest countries in the world, with little more than subsistence livelihoods and remittances to support them. Rising sea levels mean that several times a year the regular cycle of high tides on top of the ever-higher sea level brings the sea onto roads and anywhere that is low lying.



## 6.2 The impact of flooding on livelihoods and living conditions

Increased rainfall leads inevitably to increased volumes of water in streams and rivers. This can lead to flooding at vulnerable locations and sometimes to damage to existing riverbanks and to flood protection works, including levees and dikes. Where the bank is overtopped, rapid flow over the top of flood protection dikes can lead to progressive failure and collapse, causing major flood damage and death in the surrounding areas. Even where the water level is not too high for the bank, greatly increased volumes of water will lead to a river or stream flowing much faster. If the bank is not lined, it can erode, which leads to flooding. This can destroy flood-control banks and other structures that would otherwise have been able to contain the water.

Even in areas where rainfall is less as a result of climate change, the rain may fall at

greater intensity leading to greater risk of flash flooding. By its nature, flash flooding is very difficult to predict and can overwhelm and destroy existing flood protection. In China, much loss of life and property has occurred when old earth dykes have been breached, causing disastrous flooding incidents. In many places, climate change will lead to shorter but more intense rainy seasons. This means that flood-control measures may also have to perform as water-harvesting systems.

## Urban and rural living conditions

Unexpected flooding can and does lead to catastrophic destruction of buildings and infrastructure. Effective flood prevention schemes should be able to prevent these, but even in highly developed countries, such as the United States, the effects of flooding caused by natural disasters can overwhelm the natural defences, as happened with Hurricane Katrina in New Orleans. Less dramatic and more frequent flooding in less developed countries does not hit the headlines but can and does cause major hardship and economic loss.

High-density slum settlements in urban areas are often close to rivers and other watercourses. They are also often in low-lying areas. This makes them liable to flooding during monsoon seasons simply because of poor drainage. Paths become

impassable, and flooding damages houses and the little infrastructure that they have. When flooding arising from a high river level occurs, they are the first to suffer and often have no opportunity to move elsewhere temporarily. As well as the health impacts, living with even small-scale flooding in a single-storey house can lead to major problems of sanitation and loss of livelihood. The fact that it occurs frequently will be a major inconvenience. Families cope with it because they simply have no alternative. Increased frequency of flooding in such areas may lead to a tipping point in communities' attitude towards it and even possibly triggering violent protests.

Low-lying agricultural areas are particularly at risk of flooding during the monsoon

***AP report 4 February 2007: "Flood Waters Reach 10 Feet in Depth, and Continue to Rise"***

*"Rising floodwaters in Jakarta, Indonesia are causing massive devastation throughout the capital city. Over 20 deaths have been confirmed, and emergency services estimate the Jakarta flood has left 340,000 Indonesian residents homeless, and 670,000 more without electricity. Three days of unceasing torrential rains have overflowed the region's rivers, causing the water to burst riverbanks and flood streets and buildings with muddy waters reaching up to ten feet in depth.*

*"Authorities in Jakarta estimate that the floods are already the most destructive to hit Jakarta in five years... The flood has cut water supplies and communications to some areas of the city as the death toll continues to rise. Medical teams and soldiers are employing boats and helicopters to reach stranded residents in need of help and care. Thousands of additional police have joined emergency workers in an attempt to handle the crisis. Rescue workers are also working to build makeshift rafts to navigate the waters so that they can evacuate residents from partially and fully flooded areas and deliver much-needed supplies to the many residents who refuse to abandon their homes and businesses.*

*"Several main roads have been closed in the city, and as buildings continue to fill with the rising waters, patients being treated in some local hospitals have been moved to upper floors. .....there is a rising fear of sicknesses like dysentery and diarrhea spreading due to the floods. The water is heavily polluted, and there is a concern about the spread of disease, a fear made all too vivid by the memory of a recent outbreak of deadly dengue fever in the region."*

season. Some residents have built their houses with stilts or on raised plots. Flooded roads and paths can make villages completely isolated. Where a village is not higher than the surrounding flood plain, increased rainfall leads to increased frequency of flooding and the village paths turning into mud.

Table 6.2: Observed impacts of climate change on health sector in South-East Asia

| Climate change | Indonesia | Philippines | Singapore | Thailand | Viet Nam |
|---|---|---|---|---|---|
| Increasing temperature and variability in precipitation | Significant increase in dengue cases in La Niña years; illness and deaths due to heat stress | Increased dengue outbreak; illness and deaths due to heat stress | Increasing cases of dengue; spreading to areas not previously found | Impacts of dengue fever significant and increasing | Increased number of dengue cases |
| Sea level rise | Spread of water-borne infectious diseases | Spread of water-borne infectious diseases | | Spread of water-borne infectious diseases | Spread of water-borne infectious diseases |

Source: ADB: *The economics of climate change in Southeast Asia: A regional review* (Manila, April 2009).

## Health

Catastrophic floods can and do lead to major loss of life. On a smaller scale, however, flooding can lead to health problems in affected areas. Flooding can overwhelm the limited sanitation and water supply facilities available in urban and rural areas. This can lead to sullage and sewage contaminating the clean water sources and causing an increase in diseases, such as dysentery, cholera, typhus and diarrhoea. Children often die of these diseases; the economic cost to the livelihoods of the poor in terms of workdays lost, even to an otherwise healthy adult, can be significant.

Where drainage is inadequate, excess water will inevitably stand and become stagnant. Where malaria, dengue and other mosquito-borne illnesses are endemic, increased levels of sickness are common. Schistosomiasis (Bilharzia) and other diseases can also arise from stagnant water close to settlements. In the event of childbirth or other medical emergency in rural areas, even modest flooding can make it impossible to get to a clinic; this increases the likelihood of death in poor rural communities.

In the Philippines, a 1998 study on the characteristics of notifiable diseases (required to be reported to government), such as malaria, dengue, diarrhoea and cholera, showed a 10–58 per cent association between health and climate variables. The study also revealed that non-infectious diseases are also affected by climate change, variability and extremes, such as shellfish poisoning, cardiovascular diseases and respiratory problems. Flooding brought about by ENSO events triggered a number of health-related problems in the Philippines. The 1997 El Niño, which was followed by a La Niña the next year, caused several outbreaks of cholera, dengue, malaria and typhoid fever in various parts of the country. Dengue cases had significantly increased since the early 1990s when the number of recorded cases averaged only about 5,000 per year. In 1998 and 2003, the number of dengue cases rose by six- to seven-fold to 30,000 and 35,500, respectively.[6]

## Agriculture and other livelihoods

Where uncontrolled flooding takes place, crops are destroyed and fields could be scoured by fast-flowing water. Loss of a family's crops can be devastating. Even where the government provides food aid to the affected areas, the local population can suffer loss of income and the funding to invest in seeds and other agricultural needs. Farmers' equipment can be damaged and destroyed. Livestock is particularly at risk and will drown if not taken to higher ground. Irrigation systems (see chapter 4) are also at risk from uncontrolled flooding.

Urban and rural small-scale industry and other livelihoods are affected by damage to

6 ADB: *The economics of climate change in Southeast Asia: A regional review* (Manila, April 2009).

workshops and other worksites. A small-scale entrepreneur or village craftsman often has no insurance. This is especially true in areas where there is frequent flooding and insurance companies will not include flooding in the risks they cover. Flooding can damage equipment so that repair or replacement is beyond the financial means of the owner.





**_Bangkok Post June 2010, Quoting Helen Clark, Head of UNDP, speaking in Hanoi_**

*"Vietnam is one of the most exposed countries in the world to rising sea levels intensity and frequency of adverse weather events like typhoons. Vietnam is planning for a one-metre rise in sea levels by 2100, which would inundate about 31,000 sq km of land – an area about the size of Belgium, unless dykes and drainage systems are strengthened, a UN paper said in December. The threat is greatest in the Mekong Delta, the country's main rice production area. If that land becomes unusable there are serious implications for the region."*

In areas close to the sea, inundation from the sea can lead to increased salinity and make land less favourable for crop production. Viet Nam in particular has suffered from severe saltwater intrusion in agricultural areas. In 1998, seawater intrusion caused severe soil salinization up to 10–15 kilometres inland. About 100,000 hectares of agricultural land in the province in the Mekong delta region) were already salinized in 1999.[7]

## Rural transport

Roads and paths are vulnerable to flooding in a number of ways. At its most basic, flooding will close a road and either stop traffic completely or force vehicles to take a lengthy detour. Both can lead to economic losses. If the road serves remote communities, this can stop the delivery of important goods, including food and medicine, as well as stopping the export of cash crops.

An unsurfaced road loses much of its inherent strength if water is allowed to enter the road pavement. Even light vehicles trying to use an unsurfaced road when it is flooded will cause damage. They can leave ruts that make it difficult for the road surface to drain effectively after the flood recedes. The effect of heavy vehicles getting stuck and trying to free themselves can lead to the road becoming impassable. A properly designed road takes account of probable flood levels, but increased flooding can affect the design assumptions. Adaptation to the flooding may involve raising the road embankment as well as installing more and larger cross-drainage structures, including culverts.

Bridge piers and abutments constrict rivers and speed up the flow. Bridges usually have some protection against this in the form of masonry or stone filled gabions. Greatly

7 ADB: *The economics of climate change in Southeast Asia: A regional review* (Manila, April 2009).



increased flood flows can lead to the undermining and collapse of river bridges. Even where a bridge is not overtopped, water flow around its abutments can undermine them and lead to collapse. Flooding of rivers adjacent to road embankments can undermine the embankments, causing the road embankment to collapse. In mountainous areas where roads often run along the sides of river valleys, this type of flooding is perhaps the major cause of significant damage to roads with insufficient protection.

In areas where the river flow is low and the cost of a bridge is uneconomical, drifts or causeways may have been used. They are low structures that permit higher levels of water to flow over them and are closed during periods of heavy rainfall. They too must be properly protected, or they can be washed away by unexpectedly high river flows.

Not all areas have roads, and communities must use footpaths even for relatively long distances. Flooding

under these circumstances can make villages completely isolated when rivers are at their height. River transport is often a major component of local rural transport systems, particularly in flood plain and delta areas. Ferries enable people to cross rivers and streams. The vessels used are often traditional country boats using flimsy jetties, but they are essential parts of the transport network in rural areas. Fast-flowing rivers and flooding of jetties can make river crossing by ferry impossible.

Funafuti, the capital of Tuvalu, is a low-lying atoll with major problems arising out of sea level rise. High tides are becoming higher and land for crops is becoming salinized. The situation has become so bad that water floods out of depressions in the ground and out of the coral itself. At these times many houses, inevitably those of the poorer people, are inundated. The airport is partially flooded at certain times of the year. Groundwater is becoming brackish, and latrines no longer work effectively. Houses are now being built on stilts, which had never been done before.

### The future

Even if all the good intentions of those who are concerned about climate change were to be put into action at once (a very unlikely prospect), the impact in terms of climate change and its impact on the lives of poor people will continue to worsen for some time. Flooding will continue to become more frequent. Adaptation is the only solution and must be undertaken quickly if the lives of poor people are not to become even more difficult.

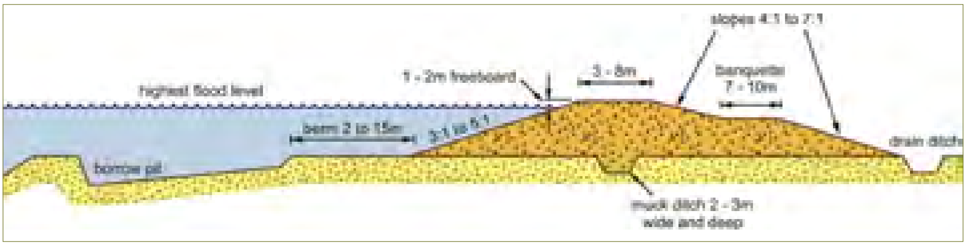
## 6.3 Various types of flood control and their components

Many types of flood-control systems and structures have been developed to protect people and property from flooding. This section describes the primary ones. Some work by ensuring that the floodwater stays out of populated areas and gets to the sea in the fastest possible time without causing damage.  Others are intended to ensure that the affected population can get above flood water level until the flood recedes in the normal course of events.

## Dykes and floodwalls

The use of dykes or floodwalls to control flooding goes back to ancient times. A dyke is usually made of earth while a floodwall is a concrete or masonry construction. Both are built parallel to the river and both must be to a similar structural standard as a dam. Dykes are usually built of material taken from borrow pits alongside the river. Where possible the dyke will be set back from the river so as to increase the cross section available to flood flow. The construction process (but not the design process) for dykes is similar to that used for road embankments, although they usually have much flatter side slopes to avoid erosion during flooding. Other erosion control may include grasses, masonry and gabion mattresses, as appropriate. Dykes are sometimes built with a collection channel alongside to carry any overflow to a point where it can safely be discharged (figure 6.1).

Figure 6.1: Cross section of a major dyke or levee




## Sea dykes

Sea dykes have been built for many years to protect agricultural land from inundation by seawater during high tides and storms. Viet Nam has many such structures. Their use pre-dates the awareness of global sea level rises, but with increased sea levels and storms arising from climate change, they are becoming more important.

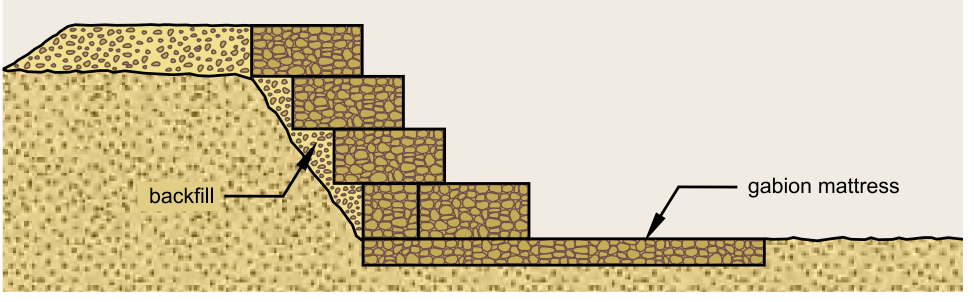
## Storm drains

Tropical rainstorms often lead to water being unable to escape from an affected area and to consequent short-term flooding and standing water. The use of storm drains to take this away to a river or stream is one of the simplest methods of flood protection for inhabited areas. Ideally, such storm drains should be lined with masonry because storm water can lead to fast-flowing water in the drains, but this may not be possible for cost reasons. Unlined drains can be used but must be set on carefully controlled slopes.

## River training and bank protection

People have protected riverbanks since ancient times to prevent the rivers changing direction and destroying or flooding settlements and agricultural land. The use of structures in or alongside the waterway directs the flow in such a way that its potential to cause damage is reduced and communities safeguarded. Where a section of riverbank is especially vulnerable to flooding, it can be strengthened by bank protection (figure 6.2). This is the addition of a concrete or other lining to the bank to protect against it against erosion or other damage from flood flow.

Figure 6.2: Gabion bank protection




## Channel improvement

A tendency to overflow at a particular point on a river or stream can often be reduced by improving the channel's hydraulic capacity. Removing vegetal growth, deepening the channel at a shallow spot and straightening bends can all help to improve flow and to reduce flooding. These are usually intended to improve matters locally, although they can have an effect on downstream flooding, and account must be taken of any knock-on effect downstream.

## Flood mitigation reservoirs

Flood mitigation reservoirs can be used to store a portion of the flood flow until such a point that it can be released safely without causing damage to the area of concern. This can sometimes be part of the function of a multipurpose dam that is also used for power generation, irrigation or water supply. During a major flood, the engineers at the dam should limit flow through sluices to avoid damage at the area in question. The design and operation of such reservoirs is beyond the scope of this chapter, which only focuses on local problems and solutions. Other flood mitigation reservoirs can be built at the local level and can also be used to harvest rainwater if the area is suffering from shorter but more intense rainy seasons.

### Flood bypasses and closed conduits

Flood bypasses are often used in major food prevention schemes. A replacement channel will be built around the area that is to be protected so that it takes floodwater before levels rise above the point where it would cause flooding in the town to be protected. Closed conduits can be used to take water under areas that would otherwise flood.

### Flood refuges and storm shelters

The building of flood and storm refuges can help to mitigate the effect of floods in low-lying areas, such as Bangladesh, that are subject to frequent flooding. Killas are 3- to 5-acre sites in which the land has been built up to a level above the worst predicted flood or storm surge. This provides an area where up to 300 families can keep their livestock in the event of flooding. They can include latrines, tube wells for water and community rooms. Killas are sometimes associated with storm shelters; they can provide a refuge for up to 5,000 people from storm winds. Storm shelters are specially built refuges in which people can take refuge when flooding is associated with strong storm winds. They often have a double function as schools or other government buildings but are built on reinforced concrete stilts and are capable of withstanding typhoon winds.

### Raising houses and villages

On flood plains, most flooding events are not particularly deep. A potential approach in those areas is to adapt to flooding by raising individual houses on stilts or rebuilding them on ground that has been built up. Raising a whole village, including the roads, is also an option and intrinsically more sustainable than building barriers to keep the flood water out. Building a raised area adjacent to the village and rebuilding individual houses on them is one way to do this. Where people live in scattered homesteads, moving them to a cluster village on raised land may be the best solution. Where land ownership is a problem, raising existing plots could be the better solution.

### Other infrastructure

Where appropriate, roads and irrigation schemes can and should be designed with flood control in mind. This could include building a road embankment higher than would otherwise be required and including flood control structures in it. It could also include making the slopes of the embankments flatter to take account of the need to limit the effect of infiltration on the stability of the embankment.

Many of these flood control techniques have been used, in various forms, since ancient times. While they may have worked well so far, and can keep water away for most of the year, they cannot necessarily handle the increasingly severe floods being experienced. With climate change, which will impact severely on the poor, flooding will become worse and we need more of these structures. They must also be much better (climate-proofed) quality.





## 6.4 How and to what extent can new flood protection mitigate the negative impacts?

The construction of new infrastructure of the types described in the previous chapter can mitigate climate change-related flooding. Simply opting for the use of reinforced concrete structures and expensive flood barriers, such as that on the Thames in London, will not be an option for developing countries. Great care must be taken in identifying options that use local resources and, where necessary, working around the inevitable flooding in innovative ways such as the building of flood refuges.

Dykes and floodwalls built alongside the river can address flooding at a given point. There are many examples of where this has been done successfully. This must be approached with care because local action outside a comprehensive plan for the river catchment may simply cause or worsen flooding elsewhere. Once it is confirmed that a dyke may be built or made higher, then local resource-based methods may be used for the construction. The repair of dykes that have been breached is essential. It is important to establish precisely why they have failed and ensure that the repaired structure is capable of doing the job for which it is being built. There must be no compromise on the quality of new or repaired dykes.

Where the shape of the land has led to an area being unable to drain and the consequence is a marshy area that floods during rainstorm, it may be possible to drain it into a nearby river or the sea. The drainage of any area that has been inundated for a long period must only be done after an environmental impact assessment, including biodiversity issues, has been carried out. In many low-income urban areas, the land's natural drainage has been compromised because it has become overgrown with vegetation and household and other waste has been thrown into it. This can lead to rainwater draining away very slowly and to persistent flooding during the rainy season. Cleaning of critical areas by work parties can overcome the problem. Purpose-built storm drains can similarly be blocked through lack of regular cleaning and other simple maintenance.

Construction of sea dykes can reduce the danger of increased salinization of land in coastal areas subject to inundation by the sea. The dykes can be built using local fill material. Some management of sea dykes is necessary to ensure that they do not interfere with natural runoff and river flow is not restricted as a result. They should be sealed only when a dangerously high tide or typhoon is expected.

The challenge for rich countries is high enough, but most have the resources and the technical capacity to deal with it. Developing countries, however, lack both the finance and the technical capacity. Taking the developing world as a whole, there is an enormous amount of work to be done. The financial cost is huge, and even those countries that receive substantial development aid will find that the cost of dealing with the challenge of climate change-induced flooding by conventional methods is simply too high. The cost of failing to invest in new assets, unfortunately, is even higher. A lot of the work to be done is very local in scope and can be carried out using local resource-based approaches to increase benefits and reduce costs. Examples of this are discussed in section 6.7.

## 6.5 What challenges does climate change pose to existing flood protection infrastructure?

Much of the current flood protection was built before there was awareness that the climate was warming and that this would lead to changes in rainfall quantity and duration. As mentioned, even where existing storm drainage, river management and flood mitigation infrastructure has been designed in accordance with good engineering practice, it has been based on the concept of withstanding a flood with a certain return period. Climate change means that earlier assumptions about the quantities of rainfall and the depths of water in rivers and other channels may no longer be valid. As the climate continues to change, even the most up-to-date set of data and assumptions on which design is based will be superseded.

The most immediately noticeable effect is that the existing flood protection infrastructure will fail to cope with floods more frequently. This may lead to an increase in the number of days of flooding and an increase in the depth of floodwater. In some cases, however, the increase in intensity of rainfall and consequent depth and speed of water flow will overtop and possibly lead to the catastrophic failure of a key piece of flood protection infrastructure. Earth dykes are especially vulnerable. Not all earth dykes will have been built in

accordance with the best practice, and a breach can result loss of life and/or major economic loss, as was the case in China recently.

The principle challenge with such infrastructure will be to climate proof it so that it

**_AP Report BEIJING Jun 25 2010_**

*The death toll from storms that have pounded southern China for more than a week has climbed to 377, the government said Friday. The toll is expected to rise as 142 people are missing and more rain is expected. [.....] That threatens to hamper rescue efforts that have seen 4.4 million people evacuated from their homes.*

*The death toll climbed from 211 in the past two days as heavy rains fell in the southern regions of Guizhou, Hunan, Jiangxi, Zhejiang, Fujian and Guangxi, the State Flood Control and Drought Relief Headquarters said on its website. The government says the flooding has caused about US$11 billion in damages. Workers and soldiers began repairing two breaches along the Fuhe river near Fuzhou city in Jiangxi province on Friday, [...days after it overflowed its banks and a dike on another portion of the river burst, forcing the evacuation of 100,000 people.*

*Thousands of soldiers and workers transported stones and sandbags to block and redirect water, with the goal of patching up the breach within the next week, the official Xinhua News Agency reported.*

*[...] Storms have pounded southern China for more than a week, collapsing 368,000 houses, as landslides have cut off transportation and rivers and reservoirs have overflowed.*

*China sustains major flooding annually along the mighty Yangtze and other major rivers, but this year's floods have been especially heavy, spreading across 10 provinces and regions in the south and along the eastern coast.*

can cope with the increased flooding. Raising the level of the earth dyke is easily done using the same techniques described later (in this section) for new dykes. There is a danger in raising earth dykes; it can form a weak point that is vulnerable to breaching. It must be done in accordance with good engineering practice, including adequate benching of the old embankment. As in the case of new infrastructure, it is important to ensure that any raising of earth dykes is done as part of a river basin-wide scheme so that the lifting of the dykes in one place does not lead to flooding elsewhere. Protecting one area alone would possibly shift the flooding into an even more vulnerable location or poorer communities. On a local scale, existing canals and other water transfer systems may be unable to cope with relatively minor increased flows, and this may lead to its becoming a source of flooding for a community that was not affected before. Indeed, the flood protection infrastructure described in section 6.3 will be challenged in the event of frequent heavy rainstorms and flood flow.

Careful inspection and maintenance is critical to the operation of all infrastructure but is a major problem in most developing countries. Simple cleaning of storm drains and other channels is also critical for ensuring that they work as intended. This should be done at the start of every monsoon season and checked after any major storm that may have washed detritus into it. Earth dykes and other vulnerable structures must be inspected by a competent person early in the dry season, and areas for repair or strengthening identified. The remedial work must be completed before the monsoon season starts. This should avoid having to deal with a much bigger and possibly catastrophic problem during a period of heavy rain and high river flows. During the monsoon season, all flood control structures must be monitored regularly. Regular maintenance pays economic dividends even on a small scale. Where the maintenance prevents catastrophic failure, it is even more cost-effective.

## 6.6 What are the issues in relation to the development of new flood protection schemes?

Now that governments accept the reality of climate change and the need to have adaptation policies and strategies, new flood protection schemes must be designed in such a way that they are sustainable. Government must set out policies that ensure that issues are dealt with at an appropriate level in the government structure of a country. National, provincial and local governments, including river authorities, must be

completely clear as to what is required of them. Flooding concerns must be included in local development planning, which must also include budgeting. Such policy must set out the importance of partnerships with communities, local governments, NGOs and donors working together to share resources and overcome local problems.

The design of new flood protection schemes must take account of likely future increases and uncertainty in rainfall and river flows. This should include, where possible, design in such a way that the scheme is prepared for future levels of water flow and for it to be modified easily in the future should experience show that event of the impact of climatic change on rainfall and flood flows is even greater than expected. New flood protection schemes should be designed in such a way that they are fail-safe. An example would be the use of concrete spillways on earth dykes and similar structures. This would ensure that the flow can be reduced without damaging the structure by allowing the water to discharge along a concrete channel into an uninhabited area and avoid catastrophic collapse.

The developmental principle that local problems are best dealt with by local action applies very definitely to flood-control works. This guide focuses on local problems and solutions. In the case of flooding, people are often aware of the source of their problem and may be better able than the technician who comes in from outside to identify the best course of action. With help, communities can prioritize the best solutions to a range of problems. New schemes to protect flood communities from the effect of the increased flooding need not be large schemes to keep water at bay behind massive concrete and steel structures. In most developing countries, this is not an option, especially in rural areas on flood plains. Acceptance that flooding is going to occur and finding a way to limit the effect on the population by adaptation is a better way forward. What works in one country or community may not work elsewhere, and it is essential that options be considered with the community who often knows what is needed much more than any outsider.

Where storm drains do exist they are frequently blocked with vegetation and rubbish. Cleaning and other simple maintenance is straightforward enough for local communities to organize for themselves. As with all other infrastructure, the importance of effective operation and adequate maintenance cannot be over emphasized. While it may seem a minor point, it is essential that the formal ownership of any particular piece of new infrastructure is clear. This is not always the case, especially when a donor country has provided it. At a time when all official bodies are short of money, they will be unwilling to spend money on maintenance they believe is not their responsibility.

## 6.7 How a local resource-based approach could contribute

## significantly to limiting the impact of climate change

Flood control is one of the local resource-based approaches to adapting infrastructure for climate change introduced in chapter 3. Flood-control infrastructure will limit the effects of climate change no matter how it is planned, designed and built. But the local resource-based approach has several benefits: Among others, it adds value during the construction process, especially in providing paid work, and by using labour rather than machines, the approach has an inherently smaller environmental footprint. This section discusses both techniques for setting up a local resource-based scheme, such as the use of gabions, labour-based earthworks, participation and community contracting, and types of flood-control infrastructure that communities can build.

The design of any comprehensive new flood-protection scheme must be undertaken by a competent technical body as part of an overall plan for a river system. This ensures that the various parts of it contribute to a well-considered overall scheme. Otherwise, action at a local level may lead to a small flooding problem at one location becoming a much bigger problem elsewhere. Repair of damage to existing schemes arising from abnormal flooding could be undertaken on a local basis, although the responsible river authority must be consulted.

## Techniques of a local resource-based approach

### Gabions

Gabions are rectangular wire mesh boxes filled with stone and tied together to form basic structures. They are mainly used for anti-erosion and soil stabilization measures in rural infrastructure works. In flood protection works, gabions can be used for building walls, protecting bridge abutments, river training and aprons for river crossings.

Gabions are used as large building blocks to shape the structure required. They are stacked in the same way as bonded dry stone masonry, providing a firm and coherent part of the structure. The walls typically have a plane outer face, preferably built to a batter for appearance and to increase resistance to overturning.

Gabions are ideal for local resource- based works on flood mitigation because:

- They offer a low-cost solution for the

design of a number of different parts and components of rural infrastructure structures.

- They are easy to build, using simple tools and need no mechanical equipment.
- The installation of gabions requires fewer skilled workers, such as masons or carpenters, and provides work for unskilled labour. This includes collection and breaking of stone for the fill, and weaving and installing gabion baskets.
- The material used is inexpensive, mainly consisting of locally available stone. Gabion wire can be brought to remote sites by porters and woven into boxes on site.
- Gabions are flexible and adjust themselves to an irregular base surface and minor movement.
- Work is not vulnerable to bad weather and can be continued when it rains. In locations with reasonably stable soil conditions, gabions can be laid in water, making them especially useful for flood protection.

### Labour-based earthworks

The construction of many of the types of flood control identified in section 6.3 includes building or increasing the height of earth dykes and the construction of raised areas, such as flood refuges, or even raising whole villages. The only economic way to do this is by using surrounding natural materials on the flood plain. Use of earthmoving equipment is one option for the earthworks, but this does little to provide work for the community. Many communities see the lack of paid work as a significant factor in their continuing poverty. Paying them to do the work required means that the community gets the double benefit of the flood protection and a cash income.

As with road embankments, it is important that labour-intensive methods are used only where they do not compromise the long-term stability of the structure, be it road embankment or a dyke. While excavation and spreading of fill can be done by hand, compaction must be done by hand-held roller or other machine. Where the fill material is to be carried a long distance, it may be better to use a tractor and trailer. The basic principles of organizing earth dyke and sea dyke construction by labour-based methods are similar to those of road embankments and the same well-tested methods of local resource-based construction can be used (see chapter 7 for more details).

### Participation

Participation of communities in planning and other decision-making is a key component of the local resource-based approach. In flood control, it is particularly relevant because the community knows better than anyone what the results of the problem are and may even be well aware of the cause. Participation is more than simply walking around the community with the district chairman or his equivalent.

Effective community planning necessitates sitting down with the communities in a process that is carefully planned. Techniques, including the integrated rural access planning, ensure that all sections of the community, including the women and the poorest, are heard and not just the most powerful or articulate. The participation process must be carried out by experienced practitioners.

## Community contracting

The use of community contracting is well suited to local resource-based works, especially where the works are localized, as with many of the flood-mitigation activities described in this chapter. They are most useful because they enable communities to take responsibility for the building or reconstruction of their own assets while being paid to do it.

Although the government or small-scale contractors can manage labour-based projects, the management of large teams of labour can be difficult. Where a community is empowered to organize such work and has a written contract, the work can proceed surprisingly quickly. Communities require significant technical support, but by paying them against outputs achieved, they know what they are being paid for. It also avoids the all-too-familiar situation in which engineering contractors are unable to deal with a large number of small activities because of limited resources.

Community contracting has many variations and the particular variant adopted depends on an assessment of what is best in a particular country or culture. As with participation, an important factor is the use of effective community consultation and mobilization.

## Flood control through local resource-based schemes

This section describes how the previous techniques can be integrated into works to help communities adapt to the increased risk of flooding arising out of climate change. Where such new work is to be undertaken, schemes can be designed in such a way as to maximize opportunities for the local resource-based approach. Floodgates, spillways and sluices must, of course, be built using competent contractors. Where the work includes ditches, earthworks, gabion work, simple masonry and similar activities, then the local resource-based methods can be used with the added benefit that local people gain economically from the work.

## Dykes and sea dykes

The basic principles of organizing earth dyke and sea dyke construction by local resource-based methods are similar to those of road embankments, and the same well-tested methods of local resource-based construction can be used.

In northern Viet Nam, sea dykes have been built for many years to protect agricultural land from inundation by sea water during high tides and storms. Their use pre-dates the awareness of global sea level rise; but with increased sea levels and storms arising from climate change, they will become more important. In places, older dykes are being repaired and heightened.

***Donor encourages labour-intensive sea dyke building with community contracting***

*British DFID funded the reconstruction of 6.5 kilometres of the Hoang Dinh sea dyke in Ha Tinh province of Northern Viet Nam. Oxfam managed the work. The work was carried out using locally available skills and resources wherever possible and maximized the use of labour intensive techniques. The Hanoi Water Resources University prepared designs.*

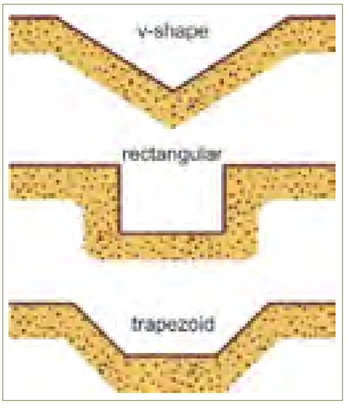
*DFID considered the project to be so successful that it funded a five-year poverty programme in Ha Tinh province that included the rehabilitation of three new sea dykes, protecting a total of 5,500 people, (2,000 in Ky Nam, 1,352 in Hoa Loc and 2,200 in Hai Phong). The use of labour-intensive approaches had been used in Viet Nam before that point, but the project led to the use of better techniques and community contracting for paid labour rather than the use of unpaid labour from the population.*

Many coastal areas in tropical countries have natural protection in the form of mangrove forests. In many places, human activities have destroyed them, causing erosion and biodiversity problems. Planting replacement or even new mangrove forests can provide protection from the sea. This is being done in Bangladesh, Thailand and Viet Nam to stop erosion of the coastline and also to contain spring tides. The approach is ideal as a local resource-based approach because it provides work for the population at the same time as it provides a sustainable solution.

## Storm drainage

The construction of storm drains is well suited to the local resource-based approach. Drains can be unlined, partially lined or lined. Unlined ditches can be built by hand with simple tools, such as hoes, picks and shovels.

Figure 6.3: Ditch shapes




A simple open V section is the standard shape for ditches constructed by a motor-grader (figure 6.3). It can be easily maintained by heavy equipment. However, it carries a lower capacity than other cross-section shapes. The rectangular shape requires less space but needs to be lined with rock or concrete to maintain its shape. This design is often used where there is limited space for drains. When excavating by hand, it is possible to construct a trapezoid-shaped drain. This shape carries a high flow capacity and, by carefully selecting the right gradients for its side slopes, will resist erosion.

If there is space available, which is often the case in rural areas, the drains can be built wide enough and with slope gradients so that they are sufficiently stable against erosion. Measures, such as grass and tree planting, will be adequate surface protection. This is only an option for ditches no steeper than 1 per cent gradient. Anything steeper will run the risk of scour. In areas where the land slopes more steeply, it is possible to keep the drain slope to 1 per cent by the use of scour checks in the drain.

Fully lined ditches are expensive and should only be provided when the threat of erosion from fast-moving water is real. This is around 3 per cent. Lining should be masonry, ideally using local stone and mortar. Partial lining in the lower part of a drain will be needed where the drain slope is more than 5 per cent. It may also be advisable in sections of drains most at risk of scouring, such as at junctions, bends and culvert inlets and outlets.

Lining of drains is done in urban and peri-urban areas where it is necessary to economize on space. Open drains cause a hazard to road users and local inhabitants if they are too deep. A rectangular-shaped drain can then be used with walls built from brick or reinforced concrete and covered with removable concrete slabs shaped to permit the entry of water. Lined drains are not quite as suitable for the local resource-based approach, but communities often include someone with the necessary skills who can be used. Where there is no one suitable, then a small contract can be made for such works. Similar principles apply to the drainage of a low-lying area that has become a swamp. The same drains can be used to provide storm drainage to the community and the ongoing drainage of the low-lying area. A good example is in the Dolores, Philippines, described at the end of the chapter.

## River training and bank protection

Gabions are commonly used for erosion protection on cross-drainage structures such as drifts, culverts and bridges. The gabions are used for protecting road approaches, abutments and piers and can also be used for building cut-off walls and aprons. Gabion mattresses are often used as part of these structures to provide a stable riverbed close to the structure. Mattresses can also be used as a foundation on which protection walls of gabion boxes are built. Gabions are also useful when building weirs to stabilize eroding gullies and the downstream areas of cross-drainage structures, which may trigger erosion and the formation of gullies. The gabions are then used to protect the soils from scouring as well as controlling the flow of the water.

Protecting riverbanks from soil erosion is often carried out using gabions in various shapes and designs. This includes bank protection against flooding where the road is situated close to rivers and streams. Gabions are also commonly placed downstream of culverts to prevent spill water from causing erosion to the land areas below the road. Similar to scour checks in side drains, gabion boxes can be used to construct check dams to slow down the flow of water in gullies. Gabion mattresses can also be used as aprons below the check dams.

## Channel improvement

The clearing of vegetation and more general cleaning of an existing natural or artificial channel all help to improve the flow of water away from an area that is prone to flooding after heavy rains. This is an ideal task for manual labour and can be done with simple hand tools. With sensible planning, this would be best done during the dry season so that the channel can be worked on by hand without undue risk to the workers. Whenever workers are required to work in the water, there must be adequate safety measures. Drainage improvements are usually intended to improve matters locally, although they can have an effect on downstream flooding and account must be taken of any knock-on effect.

### *A Philippine community takes charge of flooding control*

*In Arevalo in Iloilo City in the Philippines, parts of the community were subjected to flooding after rain that occasionally reached 2 metres in depth. Investigations showed that flow along the Calajunan creek, which drained the district area, was impeded for a 1–2 kilometre-long section of its 8-kilometre length. This was caused by heavy growth of vegetation, including Nipa palms. Fish traps and nets also contributed to the problem. This led to the effective width of the creek being reduced to 7 metres from 20 metres. Local government had no plans to clear the blockages, and the communities seemed to have no end to the flooding in prospect. Following a technical assessment, it was decided to clear a total of 600-metre length of creek. The community was involved at all stages in the planning and design of the prioritized pilot initiative, so that the chosen urban infrastructure works represented the real needs of the residents.*

If an urban community area is subject to flooding, but the flooding affects the whole of the centre of the city, it is unlikely that the problem can be solved through a small community project. However, there may be ways of reducing the problem for the community without adversely affecting their neighbours and the environment, e.g. ensuring drainage channels are unblocked to increase the flow of water and allow the floods to recede more quickly.

On a local scale, existing canals and other water transfer systems may be unable to cope with relatively minor increased flows and this may lead to its becoming a source of flooding for a community. This may possibly be addressed by small improvements to channels including the insertion of additional sluices or non-return flaps.

### *A Cambodian community closes a gate on flooding*

*In the western Cambodian town of Battambang, the Chamka Samrong Muoy community adopted a unique solution to control flooding. The severest flooding was caused by water backing up from a nearby canal and flowing into the settlement area. The engineer suggested that gates be constructed at the end of the drainage channels, which could be closed against the water in the canal when the water level rose and threatened to flow back into the community and around the houses. The community built the gate and there has been no flooding problem since.*

## Flood refuges

The construction of raised flood refuges on flood plains, such as the killas in Bangladesh, is ideally suited for the local resource-based approach. All of the fill material can be sourced locally and the building of the raised earth areas is very similar to road embankments. The surface of the refuge must be laid to a fall so that it sheds water, and some grassing of the surface would be desirable. The edges should be set at a relatively flat slope to permit access and limit erosion. Where access is limited to a single point it, would be advisable to gravel the access so that livestock, bullock carts and farm machinery can enter during wet weather without turning it into a mud bath.

## Raising houses and villages

As with flood refuges, the work involved in raising houses and villages is largely concerned with earthworks, and thus both simple and well suited to local resource-based work. It ensures that gravity helps to drain the site of floodwater rather than working to bring the flood in. Houses on stilts are one solution, but the downstairs area is often used for keeping animals and large implements so that flooding is still a problem. Many village houses are built of wood and corrugated metal sheeting, so dismantling them for reconstruction is relatively straightforward compared with a modern concrete block building.

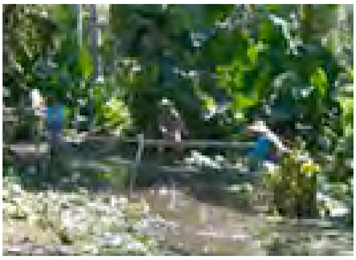
Raising individual houses is one solution and the individual householders may do it themselves provided they own the land where their house is situated. Where the house is rented and in slum areas where there is no land title, even householders who can afford it may be reluctant to invest money. As with building dykes, raising individual plots may simply make a neighbour's situation worse by interfering with local drainage patterns. The use of participatory planning overcomes this problem, provided that donor or other funding is available for raising the entire village.

## Maintenance and sustainability

Dealing with flooding using a local resource-based approach can be an empowering experience for communities. Involvement in the construction of something confers a sense of ownership. When community members remember the inconvenience of regular flooding, they will be concerned that it shouldn't reappear through simple neglect. It will be important for the maintenance obligation to be established from the very start of the participatory process.

The use of community contracting in the establishment of routine maintenance of roads offers a template for the maintenance of drains and other flood control infrastructure. A principal role of the community group is to keep roadside drains and culverts clean. Another is to report anything that needs repairing to his/her superiors. Payment takes the form of a monthly payment from government, based on the work carried out plus a retainer for the regular inspection.

**Local resource-based approach to storm drainage in Dolores, Philippines**

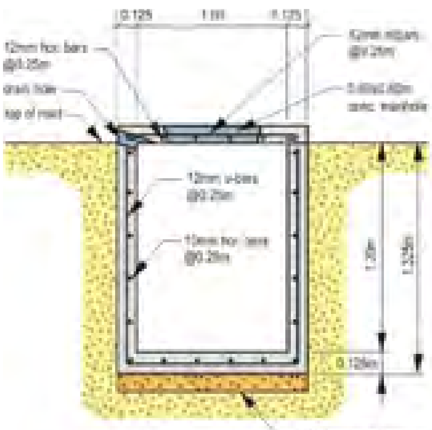


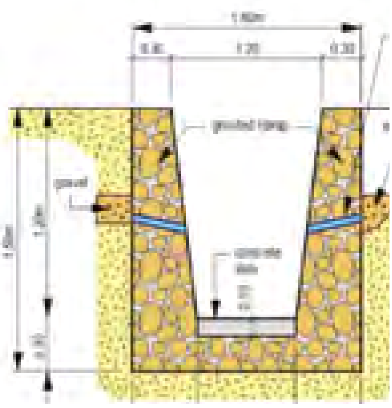
Dolores is a town next to the sea in East Samar Province in the Philippines. The population was concerned about a 5-hectare stagnant pond area that floods during the monsoon season and during typhoons. The pond was also thought to be a source of Schistosomiasis and other diseases in the urban and peri-urban areas affected by runoff.

Before any work was undertaken, an environmental assessment was undertaken which showed that there were no biodiversity issues in the swampland.

A 1 kilometre-long drain was built from the swamp area to the sea. This drained the swamp and provided improved storm drainage in the areas of town through which it passed. The municipal engineer's office undertook physical planning and technical design. The drain was concrete lined and included both open and covered sections, depending on its location.

Community contracts were used, with communities responsible for the works in their parts of the town where possible. Women took a leading role at all levels in both the planning and building of the scheme.





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7

# Rural transport

# Rural transport

## 7.1 Rural transport and climate change – an introduction

Climate change will impact on rural transport. To discuss this sensibly, however, requires that there is a clear understanding of the nature of rural transport. Transport is the movement of people and goods by any means along infrastructure[1] designed for that purpose. Over the past two decades there has been growing recognition that roads merely provide the opportunity for movement, and that transport also includes the means by which people and goods move, whether it be a motorized vehicle, intermediate means of transport (IMT) or on foot. Thus, roads, tracks and trails and the means to travel encompass rural transport.

Investment in rural roads over the past decades has been high and represents a considerable portion of the national budget. Such investments have been conditioned by the increased understanding of rural transport, which illuminated the need to provide the means for rural people to benefit from infrastructure development.[2]

***Basic characteristics of rural transport***

*The reality of transport in the rural areas of developing countries has been well documented, with the following basic characteristics:*

- *A significant part of transport in rural areas is carried out on foot.*
- *The majority of journeys are for purposes that do not involve buying or selling anything.*
- *Vehicle ownership of any sort is very low.*
- *The transport burden falls disproportionately on women.*
- *A significant component of journeys is to meet basic needs, such as water, fuel wood and food.*
- *The amount of time and effort spent by households on transport is considerable, amounting to several hours and kilometres per day.*

1 Infrastructure in this chapter would include roads, tracks, trails and waterways.

2 See John Howe: *Inclusion of social benefits in transport planning: Overview of thematic papers and unresolved issues* (March 2003).

Further research has identified the complexity of rural transport in that household trips are made for distinct functions, in which the trip may or may not be made on a road and different means of transport may be used. At the most basic level is domestic transport, entailing the collection of water and firewood and going to fields to produce food for domestic consumption. Agricultural travel and transport relates to going to fields for different cultivation activities, movement of farm inputs, the collection of the harvested crops and crop marketing. And travel to services and for social purposes includes trips to health clinics or hospital, travel to markets, travel by children to school and travel within and outside the village associated with visits to family and friends or to engage in social obligations.[3]

The shortcomings of rural transport has been studied and recognized for the past 20 years.[4] And yet, relatively limited attempts have been made to address the issue. It is

**_Rural transport and poverty reduction_**

*"Better rural roads are a necessary but not sufficient condition for graduating from poverty. There is little evidence that roads have impacted directly in terms of reducing income poverty. The ability of the poor to make significant economic use of a road depends on their asset base and the entitlements to resources and opportunities that they can command. However, the poor benefit primarily through the indirect impacts of road improvements, of better access to state services and improved provision of services to the village, and of opportunities in alternative livelihood income streams where the preconditions for their development are right."*

M. Hettige: *When do rural roads benefit the poor and how?* (Manila, ADB, 2006).

3 J. Dawson and I. Barwell: *Roads are not enough: New perspectives on rural transport planning in developing countries* (London, Intermediate Technology Publications, 1993).

4 I. Barwell: *Transport and the village: Findings from African village-level travel and transport surveys and related studies*, Africa Region Discussion Paper 344 (Washington, DC, World Bank, 1996); J. Howe: *Transport for the poor or poor transport?* (Geneva, ILO, 1997); J. Howe.and P. Richards: *Rural roads and poverty alleviation* (London, Intermediate Technology Publications Ltd, 1984).

true that the major elements of rural transport – walking and simple means of transport – are outside the public domain and that the rural poor have limited opportunity to voice their transport problems. The move away from roads as a driver of rural development in the 1990s lost sight of the fact that rural transport in its broader sense is still fundamental to rural development. The one area where the substantive research has achieved results is in the development of planning systems, which attempt to integrate different sectors in the definition of rural access.

Despite the change in emphasis in rural transportation, its poor development is still a major constraint in many developing countries to social and economic development. The key issue here is mobility. If there is no road access or if the road is in poor condition, as is the case in many countries, rural transport services cannot reach the people and any means of transport available to rural people is rendered ineffective.

Poor rural transport hurts in a variety of ways:

- Many farmers are reluctant to grow a marketable surplus second crop because it cannot be sold or because the difficulty and expense of transport significantly reduces the returns to labour.
- Agricultural productivity is low, and there is a lack of innovation because extension information and inputs do not reach the farmers.
- School enrolment is low and absenteeism is high (often among teachers as well as children).
- Standards of health care are low because clinics are hard to reach and health workers cannot travel easily.
- Women's working days are long and arduous, largely owing to the time and effort required to carry water and fuel.

Private operators typically regard transport services in rural areas as uneconomical. This is partially due to the low ratio of passengers carried to the distance travelled but also to the state of rural roads that provoke high operation costs. Some initiatives have been successful in providing effective service; for example, rather than use conventional motorized transport, innovative operators have turned to simple IMTs such as the tricycle in the Philippines or tuktuks in several countries in the region. These IMTs are capable of delivering services even where roads are in poor condition. Community groups have also involved local people in developing services that have the advantage of being located from where trips originate (typically in the village), such as the community bus service in Sri Lanka.[5]

5 International Forum for Rural Transport and Development (IFRTD): *Lessons learnt from community bus project in Sri Lanka* (Colombo, 2009).

The situation in most countries of the region is of rural transport having severe constraints in providing services to the local communities, which allow reliable access to the economic and social services that they require. Climate change will have a significant impact on rural transport systems which are already under severe strain.

The aim of rural transport is to provide access. Access is a fundamental element of a pro-poor approach and is an instrumental element in the achievement of the MDGs;[6] this includes access to water supplies, to health centres, to schools, to government offices and to markets. Table 7.1 highlights how improved rural transport can contribute to reaching the MDGs.

Table 7.1: How improved rural transport access can contribute to achieving the MDGs

| MDGs | Rural transport impact |
|---|---|
| 1.Eradicate extreme poverty and hunger | Provides employment to rural people; improvements to low-volume local roads and associated networks of village tracks/paths could reduce poor farmers' transaction costs and expand their production possibilities (including non-farm) |
| 2.Achieve universal primary education | Village roads significantly affect increased school enrolment and attendance |
| 3.Promote gender equality and empower women | Girls' attendance significantly increased by safer roads |
| 4. Reduce child mortality | Increases attendance at primary healthcare facilities and facilitates access to better water |
| 5. Improve maternal health | Positively affects antenatal care and number of births professionally attended |
| 6. Combat HIV/AIDS, malaria and other diseases | Better access to clean water |
| 7.Ensures environmental sustainability and environmental protection | Care needed to maximize compatibility of engineering design with local environment |
| 8.Develop a global partnership for development | Work on local roads/transport can generate employment |

## The impact of climate change on the levels of access and the consequent effect on livelihoods and living conditions

The literature covering the effects of climate change does not really address the issue of its impact on rural transport. The emphasis has been on flood control, alleviating the effects of drought and the impact on agricultural production. Nevertheless, it is clear that the contribution of rural transport to improving access for the rural population will be severely compromised by the impact of climate change. Although it is clear from the literature that the livelihoods of the rural people will be affected in terms of lower agricultural yields, the increased risk of flooding and the rise in water-

6 G. Edmonds: *Wasted time: The price of poor access* (Geneva, ILO, 1998).

borne disease, there is little mention of the fact the rural communities will be made more inaccessible due to the damage caused to rural transport. The daily household travel burden will increase due to greater distances required to access water in the dry seasons. Many children, particularly girls, already have difficulty attending schools because of the limited transport options. This will only get worse with climate change, thus increasing the overall level of attendance. Access to health clinics as well as access to markets could be disrupted due to the effect of the road infrastructure. The overall effect could be an increase in the isolation of the rural population.

Climate change's impact on rural transport is not the only concern. Transport in general does not ensure access; that depends on the ability of people to travel, the mobility aspect and the location and condition of the services to which people want access. At the most basic level, water supplies will be more unreliable, given the risk of more frequent droughts and sustained hotter seasons. Water tables are likely to fall, making it more difficult to provide pumped water supply. This will require more attention to be paid to more effective water storage during the periods of rain. It is likely that sources of fuel wood will become scarcer, requiring more effective means of transporting the fuel wood or investigating other sources of fuel. Agricultural yields are predicted to fall, which could force farmers to seek other employment. However, if the rural transport system is limited, such employment may have to be found in and around the village. If the rural transport services are curtailed and yields are down, small markets may become uneconomical. Any cash crop that is available will need to be transported longer distances, thus reducing its value when sold at the more distant markets. Roads and tracks will be severely affected. Trips out of the villages will take longer and be more difficult. Evidence suggests that the longer the trips to school, the higher the absentee rate. Equally, if trips are more arduous, visits to the health clinics will be reduced.

In recent years, there has been effort to collect data on rural people's access to a road. A "road access indicator" (RAI) has been created to express the percentage of the population that is less than 2 kilometres from an all-weather road. Although the RAI is a rather imprecise measure, it does give some indication of the level of access. Figures for a selected number of countries in East Asia and South Asia are provided in table 7.2.

Table 7.2: Rural access indicator for selected Asian countries

| | RAI (%) | | RAI (%) |
|---|---|---|---|
| Cambodia | 87 | Bangladesh | 37 |
| Indonesia | 94 | India | 60 |
| Lao PDR | 59 | Nepal | 15 |
| Philippines | 80 | Pakistan | 77 |
| Viet Nam | 76 | | |
| Total East Asia | 90 | Total South Asia | 57 |

There is a wide variation between countries and between regions. And there are unsettling correlations. Although the RAI is a blunt instrument, the World Bank has shown, for instance, that there is a close correlation between the RAI and child mortality.[7] This suggests that the further removed from a road people are, the more

7 P.P. Roberts, K.C. Shyam and C. Rastogi: *Rural access index: A key development indicator*, Transport Papers No. 10 (Washington, DC, World Bank, 2006).

difficult it is to access health services. Other research by the World Bank has shown that the poorest in society travel greater distances to a school or health centre.[8] This fits with the generally held assumption that the level of access has a direct impact on poverty. There is little doubt that the predicted increase in intensity and frequency of rainfall caused by climate change will deteriorate the condition of rural roads.

Access to water is basic to all rural households. If there is no well or tap in the village, water has to be collected from a stream or river. This involves considerable time and effort by families every day. Often water is carried on rough tracks and trails. Thus the percentage of households having access to an improved water source is an indicator of access to water and the difficulty of obtaining it. Across the region, this varies considerably. In Cambodia, for example, only 20 per cent of households have access to an improved supply, while in the Philippines it is 60 per cent. As would be expected, the poorer the country the lower the percentage of households having good access to water. With climate change, the increased evaporation in rivers and streams will lead to decreased water availability for human consumption. This will inevitably result in more frequent trips to collect water if the river or stream is the only source of water. But then, soil erosion from the increased runoff will affect the quality of surface water and groundwater.

Access to health services is critically dependent on road and transport accessibility. Again, the poorer the country the more limited is the distribution of health centres or clinics. In many poor countries, the public health service is poor, and rural people will often bypass the public facility and travel further to obtain private care. Where there is an emergency or an imminent birth, the quality of access can be an issue of life or death.[9] As noted previously, there is a clear correlation between child mortality and road access. In this case, both aspects of rural transport are important. Of course, some means of transport is preferable to walking to the health centre. But even if some means of transport exists, if the route to the clinic is in poor condition, the journey time will be longer. Climate change will certainly impact on the condition and use of rural transport, making trips more difficult.

Rural transport, or the lack of it, has been shown to be one of the factors in the levels of absenteeism from school. An ILO study in Lao PDR showed clearly that the distance to school was closely linked to the level of absenteeism. If no means of transport is available, it is the girls who are less likely to attend because they will have to walk to school and the parents fear for their security. The same climate change constraints will apply in the case of access to schools as to those for health centres.

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8 World Bank: *World development report 2004: Making services work for poor people* (Washington, DC, 2004).

9 IFRTD: *Motorcycle ambulances in Malawi reduce maternal mortality* (Cameroon, 2007).

Lack of rural transport also has economic implications. Farmers who have a surplus that they can sell need to find a market. If traders cannot effectively access the village, farmers will be obliged to take the produce to market. This involves time, effort and cost. In addition, whatever they are selling will receive a lower price in the market than at the farm gate. If the produce is perishable, then there is the risk that it will be spoiled either in the transportation or due to the time taken to reach the market. Clearly, poorer transport services resulting from the impact of climate change will increase transport costs and reduce the profit that farmers can make. As well, the cost of transporting seeds and fertilizers to villages will rise due to the greater difficulty of travel.

The household responsibilities of rural men and women dictate their transport needs. Although responsibilities vary according to cultural and social differences, women generally take charge of domestic activities (such as water and fuel wood collection), child care, food production and preparation. They also have transport needs in relation to their reproductive role. This means that levels of access impact differently for men and women. At the village level, women need access to a water supply and fuel wood. They need access to ensure that their children can go to school. They need to reach the health centre, both for their children and for themselves. Generally speaking, women and girls spend more time and effort on transport (due to household chores such as fetching water and firewood), have less access to public services (including health) and face greater safety and security risks while travelling.[10]

Poor transport impacts on women in particular ways. If the paths or tracks to the water supply and fuel wood lots are in poor condition, additional time will be spent, adding to an already heavy work burden. If access is cut off during the wet season, children do not go out of the village to school, health workers have difficulty visiting the village and any problems in pregnancy are severely exacerbated. The latter can lead to higher levels of child and maternal mortality.[11]

Climate change is likely to make rural access worse for women, particularly in the wet season. This would result in fewer children going to school, particularly girls who will be needed to help at home collecting fuel wood, water and food. Greater difficulty in obtaining health care can lead to rising levels of mortality and sickness. While more limited access will also impact on men through the inability to find alternative employment in the agricultural slack season, it will have a disproportionate effect on women.

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10 K. Molesworth: *Mobility and health: The impact of transport provision on direct and indirect determinants of access to health services* (Basel, Switzerland, Swiss Tropical Institute, 2006).

11 See P. Fernando and G. Porter, G. (eds.): *Balancing the load: Women, gender and transport.* (London, Zed books in association with IFRTD, 2002).

## 7.2 Adaptation through investments in rural transport

Roads provide the facilitating mechanism for economic and social development. Transport services, whether in the form of IMTs or a bus service, provide the mobility element that allows people to take advantage of the facilitating role of roads. Without some system of rural transport, rural people are disadvantaged in that obtaining the social and economic services that they require is compromised. Improving rural transport in areas affected by changing weather patterns may help communities to adapt to any adverse impacts of such changes.

### Climate-proofing rural roads

Rural road planning and design has become a well understood and well developed science over the past 30 years. This has been due to the massive investments that have been made in rural development, of which a major part has been in rural roads. As with any form of infrastructure, engineers and planners have to be fully aware of the potential impact of the climatic elements on the proposed structure. In the case of rural roads, most of which are unpaved, the key issue is to deal with diversion of water from rainfall away from the structure of the road. Until recently, engineers and planners relied on assumptions regarding the level of frequency, based on historical data. With the effects of climate change becoming more and more understood, it is clear that the planning and design of rural roads will need to make projections of the level and frequency of rainfall in line with the predicted impact of climate change.

Many rural roads are not constructed or rehabilitated according to the standard designs or procedures set out for them. For a variety of reasons – lack of supervision, insufficient funds and corruption – very basic activities are often not implemented. In the case of earthworks, the base of the road is often not laid down in the required layers and compacted properly. This automatically renders the foundation of the road weak. Drainage is another element that is often poorly executed. Side drains are not properly constructed so as to let the water flow freely away from the road. Insufficient culverts are placed, which results in water flowing back into the foundation of the road. This obviously leads to problems when roads are being adapted for climate change as the original faults also have to be dealt with before implementing measures to adapt to the impact of climate change.

Rural road problems to be addressed will be:

- difficulty of construction caused by seasonal and flood and drought intensity;
- drainage, both off and on pavement;
- raising of embankments;
- increased cost of adaptation measures; and
- maintenance.

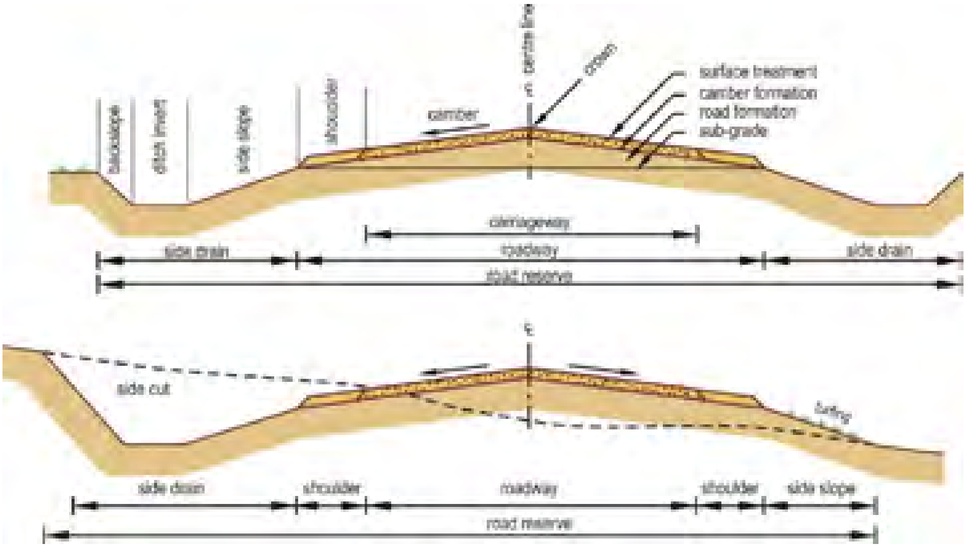
**Planning** – Rural roads are planned in a variety of ways. Those that have economic potential are still planned in relation to simple cost-benefit calculations. This compares the economic benefits that will accrue from the investment with the cost, including the life-cycle cost of the roads. Recognizing the social benefits that can be facilitated by the roads, simpler techniques based on the cost per person served are used. This aims to produce the maximum benefit in terms of the number of people with increased access in relation to the cost of construction. In addition, many rural roads are planned through participatory approaches whereby local communities identify the roads that are most beneficial to them. In the future, the planning of rural roads is going to be more difficult. In the first place, roads will have higher cost due to the adaptation measures that will need to be put in place. Within a fixed budget, selecting the most beneficial will therefore become more difficult. Second, the life-cycle cost of the roads will be greater due to the need for greater maintenance. More realistically, the assumed life of the road will need to be reappraised due to the increased impact of climate change and the acceptance that maintenance will be limited. However, these increased costs have to be seen in relation to a business as usual approach wherein the rural road network will deteriorate faster due to the effect of climate change. In consequence, rural people's access will also decrease with all the negative impact on health, education, employment and income that this will entail.

Given the probable increase in cost of rehabilitation, construction and climate proofing, serious consideration will need to be given to the most cost-effective way of providing access. Roads of course will play a part. However, the emphasis may need to be on alternative options for providing access. Consideration will need to be given to the more appropriate location of services, the provision of sustainable and trafficable tracks and the use of alternative forms of transport. In the situation in which climate change will result in higher costs for roads, a more holistic approach will need to be taken to the planning of rural transport.

**Design** – The main enemy of rural roads is water. In the design of rural roads, the key issue is therefore to ensure that precipitation is taken away from the surface and edges of the road as quickly and as efficiently as possible. In general, rural roads will have standard designs prepared by the line agency for them. It will be necessary to assess these standards in light of climate change. It is predicted that many areas will have more intense and more frequent levels of rainfall. This is likely to have an effect on required design standards. Roads in flat areas that are prone to flooding are the most at risk. Serious consideration will have to be given to the level above the surrounding terrain to which the road needs to be raised. Normally, this would be conditioned by prevailing flood levels. However, it is likely that year on year the flood levels will rise. Consequently, predictions will need to be made on the expected flood levels based on the impact of climate change. The higher the level of the road, the wider will be the total width of the road. This has implications in terms of the surrounding areas and the need to use more of the private land adjacent to the road. Increasing the height of the road also has cost implications.

The design of the road is conditioned by the topographical features of the terrain through which the road passes (figure 7.1). Engineers generally define three types of terrain – flat, rolling and mountainous. Rolling terrain is the easiest to design for, as the alignment can generally follow the existing contours. In flat terrain, the major problem is lifting the road above the prevailing flood level and ensuring that there is sufficient drainage to take the water away from the road. Clearly with the increased rainfall predicted, this will increase the effort that will need to be placed in the design. In mountainous terrain, the problems are more to do with keeping the water away from the carriageway so as to avoid scouring and rutting from water flowing down the steeper gradients. This will require more attention to good camber formation and to more effective side drains.

Figure 7.1: Rural road characteristics[12]




Another serious problem in designing roads for the impact of climate change is where the road has to pass a waterway. Simple structures designed to bridge the waterway will need to be designed for the predicted increased flow so as to avoid scouring of the structures and eventual failure. Again, this will increase the cost. Where streams are crossed by concrete fords, there may be a case for accepting that at certain times of the year the river will be impassable.

12 B. Johannessen: *Building rural roads* (Bangkok, ILO, 2008).

**Setting out** – Although design standards will need to be modified in the light of climate change, the setting-out process will be crucial for ensuring that the roads are constructed to withstand the impact. Generally speaking, rural road works can be divided into that which involves the rehabilitation of existing roads and the construction of entirely new ones. The former represents the majority of road works constructed in most countries and to the adaptation of roads to climate change.

Certain basic principles apply when setting out the alignment of the road. In the case of new roads, these principles, as follows, should be strictly adhered to:[13]

- locate the best sites for river crossings;
- avoid rocky areas;
- try to avoid areas requiring complicated drainage solutions;
- follow existing alignments to the extent possible;
- avoid steep gradients;
- minimize earth moving; and
- minimize disruption to farming activities in the area.

In the case of rehabilitation, the principles should still apply; but if this means realigning the road, an assessment should be made of whether there are ways of ensuring that the existing alignment can be improved to meet the basic principles. Realignment increases cost and involves negotiation with surrounding area land owners for the release of their land.

Mitigating the effect of climate change in relation to rural roads is not merely a question on raising the level of the road or augmenting the level of drainage. It is crucial at the setting-out stage to ensure that the topography can be used to reduce the impact of more intense and more frequent rainfall. This means setting the alignment with careful attention to the existing contours, avoiding water-susceptible soils, such as black cotton soils, to the extent possible keeping the alignment from centres of population to avoid water runoff flooding the areas, developing innovative ways to store the increased water flow to be used in the predicted periods of increased drought and avoiding deep cuts, given that the increased water flow could produce destabilization of the side slopes.

**Clearing** – This is the first operation in the process of constructing or rehabilitating the road. In general it involves the removal of all bush, trees, roots, boulders, grass and topsoil and is carried out over the entire width of the road, including the area of drainage and side slopes. Clearly, if some of the vegetation could play a part in stabilizing the edges of the road or the surrounding area, this would help in reducing

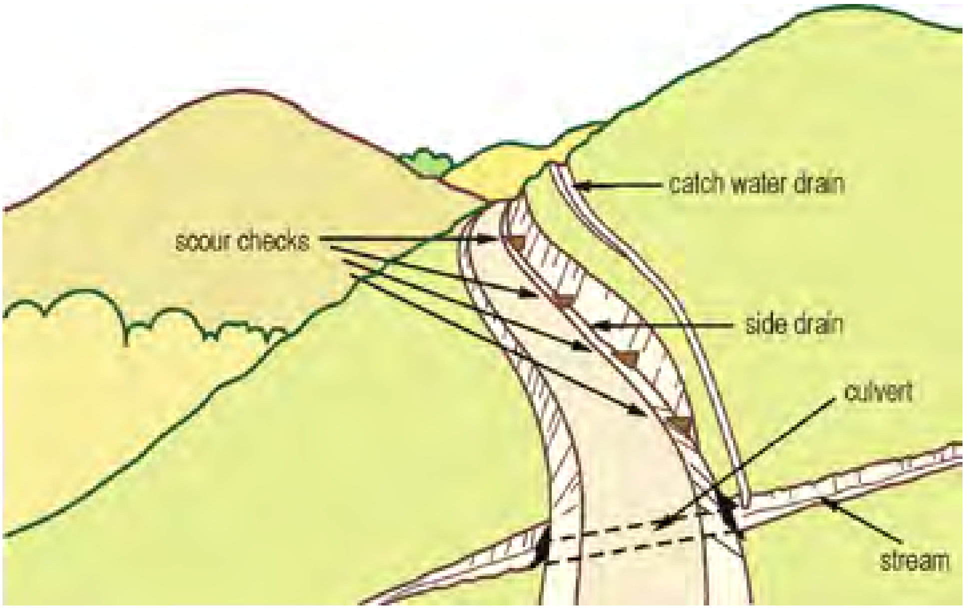
13 B. Johannessen: *Building rural roads* (Bangkok, ILO, 2008).

the impact of the predicted heavier flow of water. For this reason, in the setting-out process the alignment should, if possible, be altered so as to avoid the destruction of trees that stabilize the soil. In addition, the topsoil removed should be stockpiled to be used for covering and the side slopes and thereby assisting in the stabilization. Both activities will become important in dealing with climate change. For the clearing activity, it seems obvious that the use of labour-based methods is preferred so that as little disruption as possible is made to the existing vegetation.

**Earthworks** – Earthworks provide the foundation and in some cases the surface of the road. It is critically important therefore that the filling of embankments is carried out strictly according to the specifications set out. Whether the soil is properly laid in thin layers and compacted effectively will dictate the strength and thus the life of the road. This will not change in relation to climate change. On the completion of the earthworks, the side slopes should be protected. Placing grass on the slopes helps to stabilize the slopes.

**Drainage** – Water being the main enemy of the road, good drainage is critical to its sustainability. Water acts on a road in several ways through erosion, by weakening the structure of the road and by depositing soils and obstructing the flow of water in the drainage system. Rainwater can flow directly onto the road surface. Water can also flow on to the road through runoff from the surrounding area. In addition, ground water can rise above the water table underneath the road due to capillary action. A well-engineered road will counteract these effects through a range of interventions (figure 7.2).[14]

Figure 7.2: Drainage features of a rural road[15]




In terms of climate adaptation, drainage will be one of, if not the, prominent issues. Rainfall is expected to be more frequent and of greater intensity and this will impact on all parts of the drainage system.

Runoff from the road surface can be expected to be greater than normally designed for. One way of counteracting this would be to increase the gradient for the camber to assist the speedy runoff of water. For gravel roads, the standard camber gradient is between 6 and 8 per cent. Although there are safety issues to consider, it is likely that gradient at the top end of this range will be necessary.

In rolling and mountainous terrain, runoff onto the road from the surrounding areas can be counteracted by cut off drains that collect the water and divert it away from the road surface. This not only reduces the risk of major flows of water onto the road but also reduces the impact on the side drains. With climate change, it is likely that there will need to be an increased use and distribution of these cut off drains.

14 These include road surface drainage, side drains, raising the level of embankments, catch water drains outside the road area, scour checks to slow down the flow of water and culverts leading the water under the road and away from it.

15 B. Johannessen: *Building rural roads* (Bangkok, ILO, 2008).

The function of the side drains is to take away the runoff from the carriageway in a manner that ensures that it does not seep back into the structure of the road. Although prediction of future rainfall will be difficult, it seems clear that side drains will need to be larger to take account of the increased flow. Another, more costly intervention would be to line the side and back slopes of the drainage canal to provide more efficient flow of the drain.

In mountainous areas or in rolling terrain where there may be some steep gradients, the speed of flow in the side drains can be such that the water damages the drain through scour. In this case the normal practice is to provide scour checks (figure 7.2). The frequency of these scour checks will need to be increased, given the expected increased flow of water.

Culverts are used to take the water from the side drains under and then away from the road. These are designed based on the predicted flow of water in the drain. With the impact of climate change, designs will need to take into account the future predicted flow of water.

All roads should receive both routine and periodic maintenance. Routine maintenance, while inexpensive, can prolong the life of the road and delay the time when periodic maintenance is required. Given the lack of funding for maintenance, it is generally true that routine maintenance should be a priority. This is even more the case in relation to the effects of climate change, which will result in more intense and more frequent precipitation. Routine maintenance activities are aimed at ensuring that the effects of water on the road previously described are limited. Emphasis is placed on keeping the side ditches clear of debris and obstacles to the flow of water and ensuring that the culverts are clear for the free flow of water. With climate change, routine maintenance becomes even more important.

**Pavement** – Rural road pavements consist of two types. The first is generally referred to as unsealed pavement and consists of earth, gravel or aggregate. It is used for roads that are intended to carry a low volume of traffic. The second type is sealed pavement. The top layer of the road can be a bituminous mix, concrete, stone or brick. Such surfaces are used for higher traffic volumes or within villages or peri-urban areas. Clearly, sealed roads are more expensive than the unsealed.

Sealed roads can more effectively resist the impact not only of higher traffic levels but also of adverse climate. Increased and more frequent rains are likely to make sealed roads more attractive if the whole life costs of the road are considered. Nevertheless, this will again involve increased cost. Climate change will strengthen the argument for stage construction so that the increased costs can be spread over a longer duration. To reduce costs, more attention will need to be given to spot improvements. In this case, specific sections of the road will be rehabilitated to a higher, sealed standard in areas where climate change impact is likely to be the most severe. This is currently applied on steep slopes where an unsealed pavement would be subject to severe distress. With climate change, the same approach could also be applied to flat areas liable to flooding.

What needs to be considered therefore is whether there are other ways of increasing the accessibility of rural people in addition to the provision of roads alone.

## Promoting waterways and river transport

Waterways are important in many countries; in certain countries, Bangladesh and Viet Nam for example, they are a key element in the rural transport system. And yet, river transport is largely ignored in transport policy and regarded as a very minor element of the rural transport network. With few exceptions, data on the quantity of goods or people dependent on river transport is not available. In addition, where river transport is of importance to the rural population, there are direct and indirect employment and income implications. For many of the poorest people in the world, water transport is the only means of mobility and access to basic services.[16] For people living in the delta region of Bangladesh and Viet Nam and the along the Tonle Sap inland lake in Cambodia, for example, water transport is often the only means of access that they have.

It can be argued that in areas where river transport is feasible, serious efforts should be made to integrate river transport with road transport. Rural roads are expensive, and it is reasonable to speculate that an integration of roads and river transport would be a cost-effective solution to access problems. Unfortunately, roads are often in competition with river transport. In the Mekong Delta of Viet Nam, for example, the costs of road rehabilitation are at least twice that of other parts of the country and the rehabilitation of roads costs as much as seven times that of renovating the canals.

Climate change will have a significant impact on river transport. Increased flow in the rivers due to increased precipitation and the melting of glaciers will put a major strain on the already limited infrastructure supporting river transport. This would apply to wharves and jetties but also to the houses that are built around and also on the water. Water management schemes concerned with flood control and irrigation will need to be planned, considering the impact of climate change on river transport. Currently, such planning is often in conflict with river transport.

### *The importance of waterways*

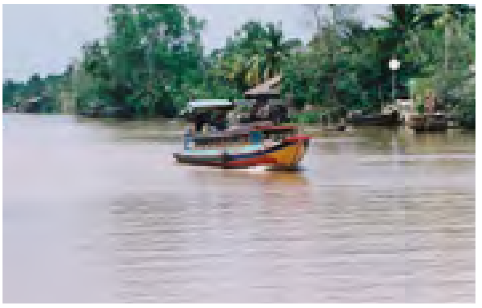
*From Cambodia's Tonle Sap Lake, 100 tonnes of fish are caught every day on 50 boats used by 200 fishermen in the dry season. The 150,000 people live in floating villages around Tonle Sap lake use boats to take products to floating markets.*

*Boats are also used to carry consumer products and medicines to remote communities and serve as shops for their owners, who are often women. Without water transport, the farmers of the Mekong Delta would be unable to take fertilizer or seed to their fields or to carry away the resultant crops to markets or wholesalers.*

*In Bangladesh, men work as boat operators transporting goods and passengers along the waterways. The boats provide an estimated 60 per cent of all employment in the transport sector and are the main source of income for 4 million people supporting 10 million dependants.*

Sources: C. Palmer: "What is rural water transport?" Waterways and Livelihoods, research project,London, IFRTD, 2003;N. A. Chowdhury: *Bangladesh inland water transport and rural livelihoods: Case of AmtaliUpazila, Bargunadistrict* (IFRTD, 2003), http://www.ruralwaterways.org/en/case/case.php

16 C. Palmer: "What is rural water transport?" Waterways and Livelihoods, research project,London, IFRTD, 2003.



The case of waterways again point to a more holistic approach to planning of rural transport in the light of the impact of climate change. The key feature of this approach would be the focus on access. Rather than emphasizing infrastructure alone, the approach would take as its objective the improvement and sustainability of access.

## Enhancing mobility and accessibility

Assessing the impact of climate change on rural transport infrastructure is relatively simple compared with that of the impact on mobility and accessibility. Mobility and accessibility are concerned with people, facilities, goods and services, with market forces and with a range of issues, such as the changes in agricultural practices and the resilience of local communities.

It is possible to adapt roads and tracks and trails to climate change. If so, then mobility will be sustained and rural transport services can be supported and can provide the access that the infrastructure facilitates. On the other hand, if the infrastructure is unable to withstand the impact of climate change and/or no maintenance is applied to the roads, the transport services will function for only a short time after the completion of the road.

Adapting rural transport will have a cost. This cost will primarily relate to adapting the infrastructure and to increasing the level of maintenance. It is probable that the increased cost will mean that stark choices will have to be made by governments on where to apply the funds for rural transport. The cost of adapting rural roads to climate change will limit the funds that could be available to provide full access to all communities.

Given the difficulty of responding to all the demands that climate change adaptation will make, it is sensible to assess what can be done by local communities to improve their own mobility and sustain their levels of access. This should involve an assessment by the local communities of what level they actually need. Whatever efforts are taken to improve transport infrastructure, it seems clear that a range of interventions will be necessary to overcome the impact of climate change and help communities to adapt to these changes. More emphasis will need to be placed on local solutions. It will be necessary to promote more vigorously some of the appropriate means of improving mobility.

Dealing first with mobility at its most basic recognizes that transport at the village level is mainly carried out on foot. This is partly because of the lack of any other means of transport but also because transport services cost money and villagers often have a limited budget. Nevertheless, improvements can be made at the village level to improve the mobility of the people. The provision of simple walkways, either within the village or to services in the vicinity of the village, can be constructed.

Transport involving some form of vehicle, whether motorized or not, has been the subject of several programmes over the years. Bicycles, for example, do not require a fully developed road, so rather than building roads to accommodate four-wheel vehicles, simple concrete tracks can be provided. The focus of adaptation measures in relation to the means of transport will not be so much in designing new devices to deal with increased water flow and precipitation. Rather, it will be the adoption of a different view of rural transport where the means of transport are in the hands of the local communities.

In the Asian region, one of the causes for optimism for the ability of local people to access some sort of transport is the range of simple transport means that are available. Most of these are not provided by outside sources but developed by local people through innovative use of the existing resources. Many of these vehicles are capable of dealing with poor or bad road conditions. IMTs cover a wide range of transport vehicles, from manually powered to simple machine-driven vehicle. In some countries, they have become part of the transport hierarchy. In the Philippines, for example, buses transport people to the main roads, jeepneys generally ply the secondary roads and tricycles use the tertiary roads, many of which are impassable in the wet season by other vehicles. Transfer points are located at the intersection of the different levels of the road network and fares are regulated by the relevant local government body.

The more formal rural transport service, reliant on four-wheeled vehicles such as buses, may have increasing difficulty in providing the service due to the degraded condition of the roads.

Although it would be convenient to believe that rural roads will be fully climate proofed and maintenance will be provided, this is probably rather optimistic. Not least because of the cost involved. Certainly one should expect that the rural roads will be in no worse situation if the appropriate adaptation measures are taken. It would be sensible therefore to encourage the wider use of IMTs with appropriate policies and regulation.

Rural access consists of three elements: the infrastructure, the means of transport and the services to be accessed.

Generally, the solution to poor access is seen to be concerned with the infrastructure and the means of transport. However, access also involves the services that the rural population requires. As well as looking at how to improve the movement of people towards the services, serious consideration should be given to locating the services closer to the people. There are two problems here. First, the idea that each village would have a market, a health centre, a primary school and other services is incompatible with the level of economic development of most of the countries in the region. Second, the planning of these facilities is generally carried out on sector lines so that education or health sector planning, for example, is often not fully coordinated with transport planning.

***Broadening access***

*"All of the case study locations demonstrated, to a greater or lesser degree, a high level of road density. Given the density of existing rural road networks in the study locations, perhaps there is a need now also to look at how to make better use of existing roads and infrastructure. This could mean designing interventions that concentrate on removing the access and mobility constraints on the poor, specifically making investments in tracks, paths, culverts, and crossings, as well as improving transport modalities and their carrying capacity, especially intermediate (non-motorized) means of transport that benefit the poor."*

Source: M. Hettige: *When do rural roads benefit the poor and how?* (Manila, ADB, 2006).

The issue of funding is valid. However, if providing more facilities closer to the villages would result in less spending on roads, an overall saving in funding could result. The issue of planning has been addressed in the last decades in developing physical infrastructure planning tools that integrate mobility, infrastructure and service location issues. The most prominent of these is integrated rural infrastructure planning (IRAP), which the ILO developed and which has been effectively used in several countries.

Climate adaptation through improving rural transport will cost money. This is evident whether this is in the adaptation measures that are necessary to climate proof rural roads and village level infrastructure or developing systems of rural transport services which can adapt more easily to the impact of climate change.

In the case of road infrastructure, this presents a major dilemma. In most developing countries, the room for manoeuvre in relation to the overall budget for rural roads is limited. The implication is that if road rehabilitation and construction costs are higher fewer roads will be built or rehabilitated. Given the level of road access currently enjoyed by the rural population in the region, especially in South Asia, this would be a major blow to the objective of providing effective access to the population.

**The high cost of climate adaptation**

*In Cambodia, an estimated US$10 million of investment will be required to construct water gates and culverts for newly rehabilitated road networks developed without factoring in increased risks of flooding. In Bangladesh, the Government estimates that raising an 800 kilometre network of roads by between 0.5 and 1 metre to counter sea level rises will cost US$128 million over a 25-year period.*

Source: UNDP: *United Nations human development report 2007* (2008).

To confront this problem will require that certain basic ideas regarding rural road infrastructure be reassessed. In recent years, considerable effort has been applied to the concept of basic access. In their comprehensive document on the subject, Lebo and Schelling define basic access as "the basic access approach gives priority to the provision of reliable, all-season access, to as many villages as possible, over the upgrading of individual links to higher than basic access standard."[17] In addition, major research input has gone into assessing how the cost of providing basic access can be reduced.[18] The emphasis of all this work is on the road (or track) infrastructure to provide basic access.

As with all aspects of the impact of climate change, much of the impact of adapting rural transport will rest with the communities. Support will need to be provided to assist communities to be part of the planning of rural transport interventions, to develop community maintenance of the infrastructure that can be provided and to develop community-based transport services.

It is necessary therefore to view rural transport in a more holistic fashion. This implies emphasizing the location of services and the means of transport in equal measure as the infrastructure. Access is the key to ensuring that rural people can obtain the services that they require to sustain their livelihoods. In the planning of interventions to climate proof rural transport, the question to be asked is how to sustain a reasonable level of overall access. As discussed, this involves not only the infrastructure but also the physical location of the services to be accessed and mobility issues. In this way, the overall cost can be shared and the total cost of sustaining access can be minimized.

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17 J. Lebo and D. Schelling: *Design and appraisal of rural transport infrastructure: Ensuring basic access for rural communities* (Washington, DC, World Bank, undated).

18 Transport Research Laboratory: Minimizing the cost of sustainable basic rural road access. Several research papers 2002–2004.



## 7.3 Adaptation through a local resource-based approach

As stressed throughout this guide, climate change will disproportionally affect those who have the least resources to deal with it – the poor. Assistance and resources need to be provided to mitigate the impacts on their living and working conditions. This will include resources for rural transport to at least sustain the current level of access. It is clear that rural people will need to become more involved in the planning and implementation measures. This requires a major effort on the part of government to improve the capacity of local planning systems, supporting NGOs working with local communities and providing information to local communities not only on the likely impact of climate change but also on innovative measures that have taken place to adapt to climate change. This is true in relation to rural transport as much as it is in general for rural infrastructure.

There needs to be a major awareness campaign in rural areas to alert the population to the problems that will arise as weather conditions become more severe. Rural transport will become more difficult and communities can be encouraged to consider what they can do to limit the impact. If rural roads are to become impassable for longer periods, then clearly it will be more difficult to reach basic services such markets, schools and health centres. Simple methods can also be used to improve the drainage of the road in the village, to protect the road from flooding and to improve the condition of the paths and tracks. Rivers and streams will, in the wet season, have greater flows than previously. This presents safety problems, given that crossing them will be more dangerous. Although improving the crossings through simple bridges and drifts will require resources, the work itself can be done by the local community.

Where areas are already prone to flooding, their access to water, fuel wood and their fields will be restricted. Villagers need to prepare for this eventuality by making sandbags and even constructing simple boats. In general new houses should be built with larger free space under them and, if possible, built on higher ground.

Climate change will have an impact in terms of reduced crop yields and the difficulty of movement in the wet season. This will affect the livelihoods of people. It will be important to look to alternative means of income. Wherever infrastructure works are being carried out in the rural areas, it should be considered to increase the use of local resources and provide income to those whose livelihood will be adversely affected by climate change.

***Using communications technology to overcome some access issues***

*There has been major development in access to mobile phones in recent years. Where physical access is limited, mobile phones can provide a major source of information in relation to a whole range of health, education and farming issues. In addition, while there may be periods of physical isolation caused by the limitations of the rural transport system, mobile phones can reduce the sense of isolation and provide access to some of the services from which the communities are excluded. Mobile phones then become part of the adaptation strategy.*

## Rural road infrastructure

With the impact of climate change, road construction and rehabilitation will become more expensive. It would be sensible to investigate more fully a more comprehensive access planning process in which both the mobility aspects and the location of services are considered together. Integrated rural accessibility planning involves a set of tools that can be used for such a purpose. For example, in a particular area encompassing several villages, the main problem is access to school and to health centres. Rather than building roads to connect all the villages to a school and health centre, equal consideration should be given to the construction of classrooms and health centres closer to the villages. Clearly a costing exercise would need to be undertaken to assess the most appropriate mix of road and school and health centres. However, by taking access and not road connection as the key issue, a more cost-effective solution may be found. It is crucial that the local population participates in such a process.

Planning of rural roads is often carried out in relation to certain criteria. Clearly, the social and economic benefits that would derive from the construction or rehabilitation of the road are important. So too is the role of the road in relation to the overall network of roads in the area. Nevertheless, the road is generally planned as providing benefits inherent in its use. This does not take due account of the fact the road is merely a facilitator for economic and social development. Rural roads

are sometimes planned in relation to agricultural programmes. However, rural road planning is generally not done in collaboration with other sectors such as education and health. Rural roads should be planned in an integrated way.

Design standards for rural roads are based on a variety of factors – the type of terrain, the volume and type of traffic expected and the climatic conditions. Various aspects of the design will need to be adjusted for the increased and more frequent precipitation caused by climate change. In flat areas, the height of the embankment above the surrounding land may need to be higher than under current design standards. The gradient of the road camber may need to be increased. Side drains will need to be larger and perhaps also lined. Culverts will need to be more numerous and probably larger, particularly in flat areas. In mountainous areas, a greater use will need to be made of both scour checks and cut off drains. All of this of course will come at price.

Road engineers will be in a difficult position of having to design rural roads based not so much on historical data but on their best estimates of future rainfall and consequently of runoff and flooding levels. Given the uncertainty, it may be necessary to make much greater use of stage construction. In this way, changes could be made to the road structure over time, as the extent of climate change becomes clearer.

***Small design changes, bigger cost***

*Raising the embankment of a 4.5 metre road, which is currently 0.5 metre above the surrounding land, would incur cost. For example, assuming a wage level of US$2.5 per day, raising the level by a further 0.5 metre would increase the cost by around US$4,500 per kilometre. Raising it by 1 metre would cost US$10,000 per kilometre.*

Maintenance extends the period before which the road needs periodic maintenance or, in the long term, when it has to be fully rehabilitated. In addition, maintenance activities are basically simple and many of them can be carried out manually by people from the areas surrounding the road, providing much needed additional employment and income. Routine maintenance of roads is essentially a labour-intensive activity and can therefore provide income to the local people. Maintenance can be carried out through small-scale contractors, community contracting or team-based maintenance groups.

Experience shows that a more local resource-based approach could reduce the cost of road rehabilitation and maintenance.

## Mobility and rural transport services

Transport services in the rural areas cover a wide range of modes and means. These can be public or private, individual, communal or business provided. With climate change, the transport burden carried by many rural households is likely to increase. Water sources may dry up in the dry season and fuel wood may become more difficult to obtain.

Measures therefore to reduce this burden have a significant impact on removing the amount of non-productive time spent on transport. Simple measures, such as well-constructed footpaths and providing footbridges, can be very effective. Flooding in settlements is likely to get worse, making domestic transport activities even more difficult. And providing solid surfaces to the footpaths with bricks or logs can significantly increase their passability.

As for transport services out of and into villages, the situation will largely depend on measures taken to climate proof the rural road network. If the roads are in poor condition, private operators are likely to curtain their services. Public transport services in the rural areas of most countries are limited and may become even more so if the roads are impassable for longer periods. Greater reliance therefore may have to be placed on simple means of transport on roads that are impassable to four-wheeled vehicles.

A local resource-based approach focuses on the use of local labour and materials and emphasizes the use of local capacity in the whole process of developing physical infrastructure. The approach applies not only to the use of local labour and material but also to local-level planning, the use of local contractors or community groups for doing the work and forming users' groups to monitor and supervise. Local communities can be encouraged to make use of simple means of transport based on bicycles, motorcycles and single-axle tractors.

Road rehabilitation and maintenance has of course been the main sector in which the approach has been used and proved successful. In relation to the work that will be needed to adapt roads for climate change, labour-based methods are particularly appropriate. Given the knowledge of local people of the changes that will take place, they are well placed to participate in the planning, design and implementation of the works required.

***Addressing the whole transport picture***

*"All rural transport interventions should address the complete transport picture, looking at mobility as an integrated solution along with complementary transport infrastructure and means of transport. Inclusive, participatory methods involving all stakeholders are essential to determine infrastructure priorities, appropriate locations for facilities, and suitable means of transport.*

*Promotion and subsidies have little long-term effect unless the transport means being promoted are appropriate to the environment and to people's real and perceived needs. Programmes often have disappointing outcomes when they fail to distinguish between aspirations and realistic economic possibilities."*

Source: P. Starkey, S. Ellis, J. Hine and A. Ternell: *Improving rural mobility: Options for developing motorized and nonmotorized transport in rural areas* (Washington, DC, World Bank, 2002).

As an example, in flood-prone areas roads need to be built above the flood level. However, the flood levels are becoming unpredictable. The design can no longer depend on records of past floods but will need to respond to the increased flood levels caused by climate change. This will require the involvement of the local people. Raising the embankments in these areas will imply that the total width of the road becomes greater and is likely to encroach on the land that is being used by the farmers. This will require negotiation with the owners, which is often best carried out through the village and community committees.

Rural people have little access to resources. The resources they do have are both communal and individual. At the community level, it is possible for them to draw on the knowledge of the members of the community in finding solutions to their access problems created by climate change. This may be through formalized processes, such IRAP, or through more informal discussions as a group. Given that the problems they will face will have to be mainly solved by them, the community will need to participate collectively in defining and being part of the solution.

At the individual level, one of the major assets that they have is their own labour. In terms of the implementation of climate proofing the infrastructure, labour-based methods can be used. The local resource-based approach has been tried and tested in many countries over the past 30 years. Often they have been ignored partly because the programmes that are most amenable to labour-based methods have been

designed and paid for by external agencies. With climate change, it is clear that local communities will have to rely to a great extent on their own resources. The local resource-based approach is ideally suited to this situation.

In infrastructure works implemented by the government agencies, contactors are often employed. These contractors may come from the area but often do not. Generally their mode of operation is equipment based. A local resource-based approach would encourage and empower communities to contact work to local contractors and to ensure that they used local labour to the extent possible. Community contracting procedures have been developed and effectively used in several countries. Simple contact forms allow communities to both procure and monitor the works, with some technical support from the local government agencies.[19]

The local resource-based approach has many advantages in the context of climate change. It seems clear that communities will need to rely to a significant extent on their own resources in adapting to the impact of climate change. This is not to suggest that governments will be unwilling to support them, merely that they may be unable to provide the resource that are required given the pressure that will be on the national budget in the face of the mitigation and adaptation measures that will be required on a national scale. The local resource-based approach has been demonstrated to be successful in providing local communities with the support for them to use the resources that they have more effectively.

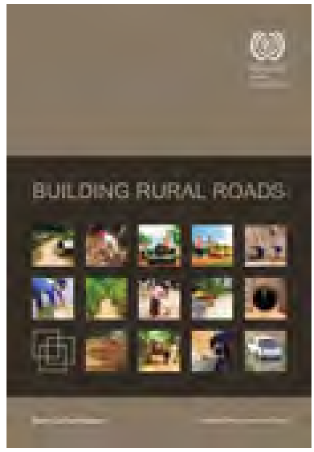
The approach places the emphasis on local people and institutions using their own resources in the development of access solutions. This is going to be particularly relevant as local communities tackle the impact of climate change. In relation to rural transport, the key elements of the approach relate to the infrastructure, the mobility issue and the sustaining of access to economic and social services.

19 ILO: *Community infrastructure in urban areas: Creating jobs while improving low-income settlements* (Bangkok, undated).

In relation to road, track and trail infrastructure, the approach provides detailed guidance on how this should be planned. It also shows how the majority of the activities can be implemented using manual labour.

In relation to mobility issues, it provides information on the types of transport services that could be provided from the community, how to reduce the burden of domestic transport and how to regulate transport services.

In relation to sustaining access, it provides local communities with a planning procedure that allows them to determine their access needs and ways to prioritize and cost possible solutions to the problems.




The local resource-based approach has been applied, with support from the ILO, in several countries in the region. This has been executed as part of the ILO's programme to provide both sustainable rural infrastructure while creating employment, promoting local participation in planning and decision-making and maximizing the use of local organizations, local materials and local contractors and community groups.

The ILO has been heavily involved in areas that have suffered from severe shocks such as the tsunami in Indonesia. Work that began as relief has changed over time to development support, using local resources to the extent possible. Rural roads have been rehabilitated using labour-based methods. Simple low-cost pavements have been developed in the rehabilitation of the roads. In the aftermath of the flooding in Pakistan, labour-based techniques have been recommended for the rehabilitation of the rural road network. In the Philippines, local community groups have been involved in the strengthening drainage and flood control structures designed with the impact of climate change in mind.

## Summary

A local resource-based approach to rural transport has particular relevance to climate change adaptation. It is predicted that one of the impacts of climate change may be a reduction in agricultural yields. In consequence, rural people may lose part of their traditional income source.

Rural transport enhances access; improved access results in increased livelihood opportunities and thereby income generation. A local resource-based approach maximizes the impact of the provision of access by providing employment and income opportunities. Moreover, the approach focuses on finding local solutions to local problems, and this can be applied to the manner and mode in which rural transport services are provided.

More indirectly, increased local expenditures will boost the local economy while an increased local income should result in further stimulation of the development of small and medium enterprises. The approach could link with micro-enterprise development to promote an effective use of additional earnings and local investments.

Climate change will place an increasing load and responsibility on local bodies. A local resource-based approach increases the short-term impact through employment creation but also the long-term impact through local planning and ensuring sustainability. The sustainable rural infrastructure strategies inherent in the approach emphasize local participation during the identification, planning and implementation stages. It is proven that a response to and involvement of people's demands is more likely to lead to peoples' ownership and maintenance.

The local resource-based approach also focuses on developing the capacity of local government and bodies. This will become more important with the need to find local solutions to the impact of climate change on rural transport and the risk of reduced access of the rural population. Efforts to improve the capacity of local bodies – an intrinsic component of the local resource-based approach – will contribute to strengthen local governments related to one of their main responsibilities, local infrastructure development. This will have an impact on good governance and decentralization. Local governments will be able to do more rational planning and respond better to the demands and the real access needs of the people. Developing the capacity to involve the people will result in improved accountability and transparency. The local resource-based strategies seek to optimize the involvement of local communities in the identification, planning and implementation of infrastructure works, of which rural transport investments are a major component.

The emphasis on participation in the approach takes place at two levels; in the village to identify priorities and at local decision-making bodies to decide on priorities. Adequate participation facilitates and supports the political process of decision-making and resource allocation. In turn, this will strengthen the decentralization effort while contributing to sustainable rural transport investments.

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8

# Forestry

# Forestry

## 8.1 Forestry and climate change – an introduction

The world's forests are one of the most important of natural resources. They provide many services, including industrial wood products, numerous types of non-wood forest products, water supply and soil protection, fisheries protection, flood and drought protection, biodiversity and recreational resources.

The economic status of forests is significant.[1] Overall, the forest sector provides 1.2 per cent of global GDP, with more than 10 per cent of GDP in the poorest countries and about 5 per cent in many developing countries. The number of workers employed both formally and informally in the forest sector are approximately 30 to 140 million[2] Furthermore, the World Bank estimates that roughly 1.6 billion people rely on forests to varying degrees for their livelihoods, including 60 million indigenous people who are fully dependent on the forest and another 350 million people who live within or near forest and depend on it for food, income, shelter and food.

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1 UNEP: *Green jobs: Towards decent work in a sustainable, low-carbon world* (Nairobi, 2008).

2 P. Poschen: "Globalization and sustainability: The forestry and wood industries on the move - Social and labour implications", in *European Tropical Forest Research Network News* (Autumn/Winter 2003), pp. 43–45; World Bank: *Sustaining forests: A development strategy* (Washington, DC, World Bank, 2004), p. 16; and R. Kozak: *Small and medium forest enterprises: Instruments of change in the developing world* (Washington, DC, Rights and Resources Initiative, 2007).

In 2006, FAO reported that forests then covered nearly 4 billion hectares. In Asia, forests and other wooded lands covered 678 million hectares, or approximately 35 per cent of the total land area.

It is clear that the world's forests are under significant pressure. Between 2000 and 2005, an average of 12.9 million hectares of forest were destroyed each year, of which 6 million hectares were primary forests, biologically diverse forests that previously were relatively unharmed by human activities. From a global perspective, natural and plantation forest areas are increasing in the developed countries, while forest destruction is concentrated in poor and developing countries. Overall, there was a large net decline in forest area, and the greatest losses occurred in the tropical forest regions of Africa, South-East Asia and South America.

Table 8.1: Forest areas for Asian countries 2005

| Country | Area in 2005 (1 000 hectares) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Primary | Modified natural | Semi-natural | Productive plantation | Protective plantation | Other wooded land | Total forest and wooded land area | Total land area | Forest cover ratio |
| Bangladesh | - | 592 | - | 195 | 84 | 58 | 929 | 13 017 | 7% |
| Bhutan | 413 | 2 529 | 251 | 2 | - | 611 | 3 806 | 4 700 | 81% |
| Brunei Darussalam | 278 | - | - | - | - | 160 | 438 | 527 | 83% |
| Cambodia | 322 | 10 066 | - | 59 | - | 270 | 10 717 | 17 652 | 61% |
| China | 11 632 | 114 332 | 39 957 | 28 530 | 2 839 | 87 615 | 284 905 | 932 742 | 31% |
| India | - | 32 943 | 31 532 | 1 053 | 2 173 | 4 110 | 71 811 | 297 319 | 24% |
| Indonesia | 48 702 | - | 36 394 | 3 399 | - | - | 88 495 | 181 157 | 49% |
| Japan | 4 591 | 9 955 | - | - | 10 321 | - | 24 867 | 36 450 | 68% |
| DPR Korea | 852 | - | 5 335 | - | - | - | 6 187 | 12 041 | 51% |
| Rep. of Korea | - | 4 901 | - | 1 364 | - | - | 6 265 | 9 873 | 63% |
| Lao PDR | 1 490 | 14 428 | - | 223 | 1 | 4 643 | 20 785 | 23 080 | 90% |
| Malaysia | 3 820 | - | 15 497 | 1 573 | - | - | 20 890 | 32 855 | 64% |
| Mongolia | 4 733 | 5 407 | - | 112 | - | 2 388 | 12 640 | 156 650 | 8% |
| Myanmar | - | 31 373 | - | 696 | 153 | 10 834 | 43 056 | 65 755 | 65% |
| Nepal | 349 | 384 | 2 850 | 43 | 10 | 1 897 | 5 533 | 14 300 | 39% |
| Papua New Guinea | 25 211 | 4 134 | - | 92 | - | 4 474 | 33 911 | 45 286 | 75% |
| Philippines | 829 | 5 713 | - | 304 | 316 | 3 611 | 10 773 | 29 817 | 36% |
| Sri Lanka | 167 | 1 571 | - | 171 | 24 | - | 1 933 | 6 463 | 30% |
| Thailand | 6 451 | 4 970 | - | 1 997 | 1 102 | - | 14 520 | 51 089 | 28% |
| Timor-Leste | - | 755 | - | - | 43 | - | 798 | 1 487 | 54% |
| Viet Nam | 85 | 10 151 | - | 1 792 | 903 | 2 259 | 15 190 | 32 549 | 47% |
| Total | 109 925 | 254 204 | 131 816 | 41 605 | 17 969 | 122 930 | 678 449 | 1 964 809 | 35% |

Source: FAO: *Global forest resources assessment* (2005).

In Asia, there were two separate trends in forest area change between 2000 and 2005. In East Asia there was a reported increase in forest area of 19.2 million hectares, primarily in China and DPR Korea. In South-East Asia, there has been 14.3 million hectares decline in forest area, with the largest losses reported in Cambodia, Indonesia and the Philippines.[3]

3 The official national statistics in many Asian countries are often of dubious accuracy, reflecting national policy rather than real world conditions. The actual rate of deforestation may are likely to be significantly under-estimated and the rate of new forest establishment significantly over-estimated.

Table 8.2: Forest area changes in East Asia, 2000–2005

| Country / Area | Total area sq km | Total forest area 2005 sq km | Forest cover 2005 % of land | Other wooded land 2005 sq km | Total forest area 1990 sq km | Total forest area 2000 sq km | Annual change rate 1990-2000 sq km/yr | Annual change rate 1990-2000 %/yr | Annual change rate 2000-2005 sq km/yr | Annual change rate 2000-2005 %/yr | Primary forest 2005 sq km | Primary forest 2005 % total forest | Annual Loss of primary forest 2000-2005 sq km/yr | Annual Loss of primary forest 2000-2005 %/yr | Production plantation 2005 sq km |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| China | 9 598 050 | 1 972 900 | 21.2 | 876 150 | 1 571 410 | 1 770 010 | 19 860 | 1.2 | 40 580 | 2.2 | 116 320 | 5.9 | 0 | 0.0 | 285 300 |
| DPR Korea | 120 540 | 61 870 | 51.4 | N/A | 82 010 | 68 210 | -1 380 | -1.8 | -1 270 | -1.9 | 8 520 | 13.8 | -174 | -2.0 | N/A |
| Japan | 377 800 | 248 680 | 68.2 | N/A | 249 500 | 248 760 | -70 | n.s. | -20 | n.s. | 45 910 | 18.5 | 1074 | 2.3 | N/A |
| Mongolia | 1 566 500 | 102 520 | 6.5 | 23 880 | 114 920 | 106 650 | -830 | -0.7 | -830 | -0.8 | 47 330 | 46.2 | -380 | -0.8 | 1 120 |
| Republic of Korea | 99 260 | 62 650 | 63.5 | N/A | 63 710 | 63 000 | -70 | -0.1 | -70 | -0.1 | N/A | - | N/A | N/A | 13 640 |
| Total East Asia | 11 762 150 | 2 448 620 | 21.3 | 900 030 | 2 081 550 | 2 256 630 | 17 510 | 0.8 | 38 400 | 1.6 | 0 | | 0 | N/A | 0 |

Table 8.3: Forest area changes in South and South-East Asia, 2000–2005

| Country / Area | Total area sq km | Total forest area 2005 sq km | Forest cover 2005 % of land | Other wooded land 2005 sq km | Total forest area 1990 sq km | Total forest area 2000 sq km | Annual change rate 1990-2000 sq km/yr | Annual change rate 1990-2000 %/yr | Annual change rate 2000-2005 sq km/yr | Annual change rate 2000-2005 %/yr | Primary forest 2005 sq km | Primary forest 2005 % total forest | Annual Loss of primary forest 2000-2005 sq km/yr | Annual Loss of primary forest 2000-2005 %/yr | Production plantation 2005 sq km |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bangladesh | 144 000 | 8 710 | 6.7 | 580 | 8 820 | 8 840 | N/A | n.s. | -20 | -0.3 | N/A | - | N/A | N/A | 1 950 |
| Bhutan | 47 000 | 31 950 | 68 | 6 110 | 30 350 | 31 410 | 110 | 0.3 | 110 | 0.3 | 4 130 | 12.9 | 0 | 0.0 | 20 |
| Brunei Darussalam | 5 770 | 2 780 | 52.8 | 1 600 | 3 130 | 2 880 | -20 | -0.8 | -20 | -0.7 | 2 780 | 100 | -20 | -0.7 | N/A |
| Cambodia | 181 040 | 104 470 | 59.2 | 2 700 | 129 460 | 115 410 | -1 400 | -1.1 | -2 190 | -2 | 1 220 | 1.2 | -668 | -54.8 | 590 |
| India | 3 287 260 | 677 010 | 22.8 | 41 100 | 639 390 | 675 540 | 3 620 | 0.6 | 290 | n.s. | N/A | - | N/A | N/A | 10 530 |
| Indonesia | 1 904 570 | 884 950 | 48.8 | N/A | 1 165 670 | 978 520 | -18 720 | -1.7 | -18 710 | -2 | 487 020 | 55 | -14478 | -3.0 | 33 990 |
| Lao PDR | 236 800 | 161 420 | 69.9 | 46 430 | 173 140 | 165 320 | -780 | -0.5 | -780 | -0.5 | 14 900 | 9.2 | 0 | 0.0 | 2 230 |
| Malaysia | 329 750 | 208 900 | 63.6 | N/A | 223 760 | 215 910 | -780 | -0.4 | -1 400 | -0.7 | 38 200 | 18.3 | 0 | 0.0 | 15 730 |
| Maldives | 300 | 10 | 3 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | N/A | - | N/A | N/A | N/A |
| Myanmar | 676 580 | 322 220 | 49 | 108 340 | 392 190 | 345 540 | -4 660 | -1.3 | -4 660 | -1.4 | 0 | 0 | 0 | N/A | 6 960 |
| Nepal | 147 180 | 36 360 | 25.4 | 18 970 | 48 170 | 39 000 | -920 | -2.1 | -530 | -1.4 | 3 490 | 9.6 | -70 | -2.0 | 430 |
| Pakistan | 796 100 | 19 020 | 2.5 | 13 890 | 25 270 | 21 160 | -410 | -1.8 | -430 | -2.1 | N/A | - | N/A | N/A | 3 180 |
| Philippines | 300 000 | 71 620 | 24 | 36 110 | 105 740 | 79 490 | -2 620 | -2.8 | -1 570 | -2.1 | 8 290 | 11.6 | 0 | 0.0 | 3 040 |
| Singapore | 680 | 20 | 3.4 | 0 | 20 | 20 | 0 | 0 | 0 | 0 | 20 | 100 | 0 | 0.0 | 0 |
| Sri Lanka | 65 610 | 19 330 | 29.9 | 0 | 23 500 | 20 820 | -270 | -1.2 | -300 | -1.5 | 1 670 | 8.6 | -60 | -3.6 | 1 710 |
| Thailand | 513 120 | 145 200 | 28.4 | N/A | 159 650 | 148 140 | -1 150 | -0.7 | -590 | -0.4 | 64 510 | 44.4 | 0 | 0.0 | 19 970 |
| Timor-Leste | 14 870 | 7 980 | 53.7 | N/A | 9 660 | 8 540 | -110 | -1.2 | -110 | -1.3 | N/A | - | N/A | N/A | N/A |
| Viet Nam | 331 690 | 129 310 | 39.7 | 22 590 | 93 630 | 117 250 | 2 360 | 2.3 | 2 410 | 2 | 850 | 0.7 | -204 | -24.0 | 17 920 |
| Total South and South-East Asia | 8 982 320 | 2 831 270 | 33.4 | 298 420 | 3 231 560 | 2 973 800 | -25 780 | -0.9 | -28 510 | -1 | 0 |  | 0 | N/A | 0 |

Large-scale deforestation and forest degradation will diminish the services provided by forests. Table 8.4 describes the sort of impacts associated with deforestation. Protecting forests from deforestation, reducing the impacts of harvesting through sustainable forest management and enhancing forests through rehabilitation and development of new forest areas may significantly contribute to improved forest production potential, avoided emissions, conservation and improvement of water and soil resources, mitigation of flood damage, protection of fisheries and preservation and enhancement of biodiversity.

Table 8.4: Major impacts caused by deforestation and inappropriate forestry practices

| Impact | Description |
|---|---|
| Loss of commercial timber products and NTFP | Unsustainable harvest practices will result in degraded forest lands and commonly forest area reduction. Degraded forest contains diminished standing stock and is often associated with reduced growth rates, increased proportion of low-value species and reduced production potential. |
| Loss of water resources | Uncontrolled runoff carries soil and debris into surface water, reducing water quality for drinking, fisheries and aquatic habitat, and flood prevention. Navigable waterways and dams are silted up. |
| Effect on drinking water quality | Increased turbidity reduces effectiveness of chlorination, increases adsorption of toxic materials, provides food for microbes that can then multiply in the water distribution system, interferes with ion exchange and carbon adsorption processes and with lab analysis of water analysis |
| Destruction of fisheries and aquatic habitat | Siltation kills fish, spawning areas and vegetation needed by fish to reproduce and survive |
| Flooding | Uncontrolled runoff increases flooding. |
| Siltation of waterways and dams | Turbidity and suspended solids deposit in navigable waterways (requiring dredging) and dam impoundments (shortening the useful life of the dam) |
| Crop damage | Turbidity damages irrigation systems and equipment, films form on plant leaves, reducing growth and market value, crusts form on soil surfaces inhibiting water absorption, young plant growth and soil aeration |
| Erosion of topsoil and nutrient loss | Removal of the trees, ground cover and leaf litter allows uncontrolled runoff and nutrient leaching during rains, making reforestation and farming difficult |
| Climate change | Large deforested areas can cause undesirable climate change, such as decreased rainfall, or can contribute to global warming. |
| Decreased biodiversity | Loss of sustainable forest is accompanied by loss of habitat, species and genetic diversity, and loss of non- timber harvests. |

Reasons for deforestation include conversion of forests for agriculture and settlements, intensified shifting agricultural practices, unsustainable and inefficient logging practices, and timber theft and illegal logging. The underlying causes are often complex and intractable, ranging from governance structures, land tenure systems and law enforcement to market and cultural values of forests, the rights of indigenous and local communities, benefit sharing mechanisms and poverty and food production policies. As a result, the solutions need to be tailor-made to the environmental and socio-economic conditions at national and subnational levels in each country and their institutional capacity.

Climate change is a long-term change in the distribution of weather patterns over periods of time that range from decades to millions of years. The term is now

commonly used to describe climate change caused by human activity. Global warming is the increase in the average temperature of the earth's near-surface air and oceans since the mid twentieth century and its projected continuation. Most of the observed temperature increase since the middle of the twentieth century has been caused by increasing concentrations of greenhouse gases, primarily carbon dioxide, methane, tropospheric ozone, chlorofluorocarbons and nitrous oxide.[4] Fossil fuel burning has produced about three-quarters of the increase in carbon dioxide from human activity over the past 20 years. Most of the rest is due to land-use change, particularly deforestation and forest degradation.[5]

The importance of forests to climate change and global warming is threefold:

- Forests are an importance store of carbon – an estimated 4,500 gigatons of carbon dioxide in their ecosystems, an amount larger than all the carbon found in the atmosphere.[6]
- Changes in climatic conditions can have a profound impact on forests. Increased levels of carbon can induce increased forest respiration and enhance tree growth. Conversely, forests can be negatively impacted by changes in climate-related conditions, such as fundamental changes in rainfall and temperature levels, increased frequencies for extreme weather events and climate change- induced increases in fire, pests and disease risk. Thus, increased forest growth increases carbon sequestration rates and decreases the greenhouse effect, while forest decline increases carbon emissions and increases the greenhouse effect.
- Greenhouse gasses (GHG), including carbon dioxide, trap heat in the earth's atmosphere, creating a warming, or greenhouse effect. Forested areas serve as sinks or reservoirs of carbon because carbon is part of tree and plant tissue. Thus, deforestation increases the greenhouse effect, and reforestation reduces it.

IPCC[7] concluded that there may be significant regional transitions associated with shifts in forest location and composition due to climate change. The effects of climate change on forests will depend not only on climatic factors but also on stresses from

4 Environmental Protection Agency: *Recent climate change: Atmosphere changes* (Washington, DC, 2007).

5 Intergovernmental Panel on Climate Change (IPCC): "Summary for policymakers. Climate change 2001: The scientific basis", in *Contribution of working group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, Cambridge University Press, 2001).

6 N. Stern: *Stern review: The economics of climate change* (Cambridge, Cambridge University Press, 2006).

7 IPCC: "Climate change 2007: Impacts, adaptation and vulnerability", in Parry et al. (eds.): *Contribution of working group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, Cambridge University Press, 2007).

pollution (acid rain), future trends in forest management practices, including fire control and demand for timber and land-use change. It is difficult to separate the influence of climate change from these other pressures.

In general, forests are sensitive to climatic variability and change. Climatic factors that influence forest health-temperature, rainfall, atmospheric levels of carbon dioxide and other greenhouse gases and extreme weather and fire events – are changing and are expected to continue changing due to human activities.



## 8.2 Forestry and climate change mitigation and adaptation

### Mitigation[8]

Land use and management influence a variety of ecosystem processes that affect greenhouse gas fluxes, such as photosynthesis, respiration, decomposition, nitrification and denitrification, enteric fermentation and combustion. These processes involve transformations of carbon and nitrogen that are driven by the biological (activity of microorganisms, plants and animals) and physical processes (combustion, leaching and runoff).[9]

IPCC provides a useful framework for defining land use-change activities that result in increased carbon storage through biomass accumulation and reductions in greenhouse gas emissions. These are collectively referred to as "agriculture, forestry and other land use" (AFOLU) activities and four classes of mitigation activities have been defined:

- afforestation, reforestation and revegetation (ARR);
- agricultural land management – agroforestry (ALM);
- improved forest management (IFM); and
- reduced emissions from deforestation and degradation (REDD).

As noted previously, the major contribution of land-based activities to climate change is widely recognized by the scientific community. Dominated by deforestation in the tropics, land-use change generates about 20 per cent of global GHG emissions, and if agriculture is included this rises to more than 30 per cent. Deforestation is also

8 This section quotes extensively from Voluntary Carbon Standard: "Voluntary carbon standard – Guidance for agriculture, forestry and other land use projects", VCS Association, 2007, http://www.v-c-s.org

9 IPCC: *IPCC guidelines for national greenhouse gas inventories. Agroculture, forestry and other land uses* (2006).

the leading cause of species extinctions and a significant source of water pollution, air pollution, soil erosion and the impoverishment of rural communities. AFOLU activities are unique in that they have the potential to mitigate climate change, while at the same time addressing these other pressing social and environmental challenges.

## Afforestation, reforestation and revegetation

ARR consists of activities that establish, increase or restore vegetative cover through the planting, sowing or human-assisted natural regeneration of woody vegetation to increase carbon stocks in woody biomass and, in certain cases, soils. Specific examples of ARR include:

- reforestation of forest reserves;
- reforestation or revegetation of protected areas and other high priority sites;
- reforestation or revegetation of degraded lands; and
- long rotation forestry with long harvesting cycles.

ARR includes both plantation development and natural forest revegetation activities. The future management of these forests can include harvesting, provided it is done on a sustainable basis.

## Agricultural land management – agroforestry

ALM consists of land uses and management activities that reduce net greenhouse gas emissions on cropland and grassland. ALM mostly involves agricultural activities. The forestry activities covered by ALM can be generally described as "agro-forestry".

Agroforestry focuses on the wide range of working trees grown on farms and in rural landscapes.[10] Among these are fertilizer trees for land regeneration, soil health and food security; fruit trees for nutrition; fodder trees that improve smallholder livestock production; timber and fuel wood trees for shelter and energy; medicinal trees to combat disease; and trees that produce gums, resins or latex products. Many of these trees are multipurpose, providing a range of benefits. Agroforestry provides many livelihood and environmental benefits, including:

- enriching the asset base of poor households with farm-grown trees;
- enhancing soil fertility and livestock productivity on farms;
- linking poor households to markets for high-value fruits, oils, cash crops and medicines;
- balancing improved productivity with the sustainable management of natural resources; and
- maintaining or enhancing the supply of environmental services in agricultural landscapes, for water, soil health, carbon sequestration and biodiversity.

10 See www.worldagroforestry.org/about_us/our_role_in_agroforestry

Agro-forestry activities can deliver climate mitigation results while simultaneously allowing rural communities to maintain or even enhance their livelihoods. This is important because ARR activities often require communities to forego alternative livelihoods or invest in the long term, something that is often beyond the means of the poor and underprivileged.



## Improved forest management

IFM consists of activities that increase carbon sequestration and reduce emissions by improving forest management on forest lands managed for wood products, such as sawn timber, pulpwood and fuel wood. Four general classes of activity have been identified under IFM:

1. Conversion from conventional logging to reduced impact logging. Typically, this reduces carbon emissions during timber harvesting due to: reductions in damage to other trees (for example, by implementing directional felling); improved selection of trees for harvesting, based on inventoried knowledge concerning tree location and size; improved planning of skid trails (in peat swamp forests this could include avoiding the use of canals to extract the logs – the canals drain the peat and increase carbon dioxide emissions) and roads; and, the reduced size of logging roads.

2. Conversion of logged forests to protected forests. This could include i) protecting currently logged or degraded forests and plantations from further logging and degradation; and ii) protecting unlogged forests that would be otherwise logged. Generally speaking, converting logged forests to protected forests reduces emissions (retains carbon stocks) caused by harvesting trees and increases the carbon stock as the forest re-grows and/or continues to grow.
3. Extending the rotation age of evenly aged managed forests. Trees are typically harvested at an economic or optimal rotation age; extending the age at which the trees are cut increases the average carbon stock on the land. There is no fixed period of years over which the extension should occur, but generally the longer the period, the more the average carbon stock increases.
4. Conversion of low-productive forests to high-productive forests or improving the stocking of poorly stocked forests. Low-productivity forests usually satisfy one of the following conditions: they qualify as forest as defined by the host country, but do not contain much timber of commercial value; they are either degraded or in the process of degrading due to frequent disturbance (fire, animal grazing, fuel wood gathering, etc.); or they have a very slow growth rate or low-crown cover. Activities may include the introduction of other tree species with higher timber value or growth rate, the mitigation of disturbance events, the adoption of enrichment planting to increase the density of trees, and/or other forest management techniques (such as fertilization or liming) to increase carbon stocks.

## Reduced emissions from deforestation and degradation

REDD consists of activities that reduce the conversion of native or natural forests to non-forest land, which are often coupled with activities that reduce forest degradation and enhance carbon stocks of degraded and/or secondary forests that would be deforested in absence of the REDD project activity.

Deforestation within a country can be planned (designated and sanctioned) or unplanned (unsanctioned). Planned deforestation can encompass a wide variety of activities such as:

- national resettlement programmes from non-forested to forested regions;
- national land plans to reduce the forest estate and convert it to industrial-scale production of commodities, such as soybeans, pulpwood and oil palm;
- plans to convert well-managed community-owned forests to other non-forest uses; or planned forest conversion for urban, rural, and infrastructure development; and
- decisions by individual land owners or community groups, whose land is legally zoned for agriculture, to convert their natural forest(s) to crop production or plantations.

Unplanned or unsanctioned deforestation generally occurs as a result of socio-economic forces that promote alternative uses of forested land and the inability of institutions to control these activities. Population growth and the expansion of roads and other infrastructure often leads to subsistence food production and fuel wood gathering taking place on lands not designated for such activities. Meanwhile, poor law enforcement and a lack of property rights may allow the piecemeal conversion of forested lands. Unplanned activities include, for example, subsistence farming occurring on both public lands legally designated for timber production and on public or communal lands that are poorly managed or otherwise degraded.

## Adaptation

Adaptation to climate change is a complex process requiring knowledge of climate change, determination of appropriate land use changes (that minimizes forest emissions, addresses deforestation and promotes long-term sustainable land uses, through the development of mechanisms that promote rational land use change through transparent processes) and fair allocation of costs and benefits.

Costenbader provides guiding principles supporting climate change-related forestry adaptations:[11]

1. Land and forest ownership: The successful application of adaptive land use-change programmes requires that rights to land and forests resources be clarified and assigned to stewards capable of managing forests and other lands, according to forest conservation, forest rehabilitation and sustainable management goals.
2. Participation: Legislation is required that creates or strengthens existing rules, including to ensure public consultation in decision-making so that people dependent on the forest can contribute, be taken into account in and better understand decisions on climate-related land use change. As well, legislation should support the actual undertaking of forest conservation, forest rehabilitation and sustainable land use activities, allowing joint initiatives by government, landowners and outside investors.
3. Cost and benefit sharing: Suitable incentives need to be provided to persuade stakeholders to adopt sustainable land uses and protect forests. The mere provision of formal land and forest rights, which is not supported by adequate enforcement and incentive mechanisms, may have no significant impact on deforestation.

   Secure land rights need to be supported by measures enabling forest dwellers to practise customary rights and maintain appropriate subsistence and traditional livelihoods. Forest dwellers and users excluded from the benefits of

11 Costenbader writes specifically about REDD but we apply his finding to climate change related forestry adaptation projects in general. See J. Costenbader: *Legal frameworks for REDD*, Environmental Policy and Law Paper No. 77 (IUCN, 2009).

adaptation are likely to resist the implementation of projects for fear that they will further curtail the exercise of their customary rights and threaten their subsistence practices and traditional livelihoods.

4. Commercial requirements of REDD carbon credit training: Trading of carbon credits under voluntary or compliance markets will place further requirements on forest conservation and sustainable land use projects. Specifically:
   a. Baselines projections of predicted emissions from "business as usual" scenario for each project. The baseline should be based partly on historical deforestation and associated discount rates and reasonable predictions of future emissions.
   b. Defined projects must meet the specific criteria for permanently reducing emissions that meet the criteria set by the UNFCCC. The emissions reductions, compared to the baseline, will generate carbon credits. A percentage of the total credits will be held in a buffer account while the rest will be certified as being tradable.
   c. The projects must be additional, meaning that they would not otherwise have been implemented without REDD funding. Furthermore, the project must track the transference of emission-creating activities, such as illegal logging, from the project area to other locations; so-called "leakage" needs to be monitored and taken into account.
   d. Monitoring, verification and reporting (MRV) systems need to be established that accurately track project performance and provide credible estimates of actual emissions.

## Forests, communities and Livelihoods

Forest-dependent communities and forest-based livelihoods will be directly and significantly affected by climate change mitigation and adaptation activities in several ways. Communities will be required to forsake current unsustainable livelihoods and replace these wherever possible with long-term sustainable alternative livelihoods.

For projects to be successful, communities will need to be consulted, co-opted into the planning process and engaged in the implementation of the programmes. There are three critical elements relating to supporting community involvement in climate change mitigation and adaptation:

- For mitigation and adaptation to be successful, communities need to be incorporated into the decision-making process. In addition, consultative processes need to be developed and implemented at all levels of society (including forest-dependent communities) that enable comprehensive consultation and permit "free, prior informed consent" to be sought and obtained.
- A comprehensive framework and informed and capable community may not be sufficient catalyst for community involvement in forest climate change mitigation. Incentives that share the costs and benefits of mitigation projects may need to be established. Benefit sharing recognizes the basic rights of forest-dependent communities to rights over, and access to, forest resources.
- Forest-based climate change adaptation will require both the cooperation and the direct involvement of local communities. Local communities will be required in many cases to implement the adaptation projects. Communities will require support and capacity building to enable them to fulfil these important roles.

Communities in many regions of the world have always used and managed forests near their settlements. On a global scale, communities today exercise use and management rights over a large forested area – at least 10 per cent, or 400 million hectares.[12] The area they use and manage is even greater if informal use and control are included.[13]

Over the years, the range of activities falling within community forestry has widened considerably. Community forestry is practised in widely different settings. An analysis of these situations suggests a number of conditions that are necessary for its successful implementation. An overriding prerequisite is that it must be apparent to the people that the benefits to be obtained are relevant to them and are sufficient to justify their participation. Forestry systems for rural communities will seldom succeed unless the people concerned are persuaded of the systems' usefulness.

12 A. White and A. Martin: "Who owns the world's forests? Forest tenure and public forests in transition", in *Forest Trends* (Washington, DC, Center for International Environmental Law, 2002).

13 A. Agrawal: "Forests, governance, and sustainability: Common property theory and its contributions", in *International Journal of the Commons* (2007) 1(1): 51-76.

## 8.3 Local resource-based strategies for climate change adaptation through community forestry

Community-based forestry projects allow communities to adapt to the impacts of climate change in two main ways:

1. Forest and agroforestry activities broaden and the range of species and crops used by the community, thereby strengthening the ability of the community to generate income in the face of climate change.
2. Tree planting can substantially mitigate the impacts of, and provide protection from, extreme environmental events, such as flooding, slips and landslides and fires.

Planting trees allows communities to diversify land use. If climate change results in the failure of temporary or permanent crop failure, then communities need to respond by developing alternative livelihoods. Tree crops can be developed in conjunction with existing agricultural land uses through the use of agroforestry systems. Pure forestry crops can also be developed on land unsuitable or unprofitable for agriculture land use. Natural forest areas can be better managed to provide a wide range of timber and non-timber products.

Planting trees allows communities to become more resilient in the face of climate change and extreme climatic events. Many tree species are themselves often resilient to changes in climate and extreme climatic events than annual crops. They can often produce crops under variable climatic conditions and can recover productivity more quickly and at lower cost than many annual crops.

Trees mitigate the negative impacts of climatic events by a range of means. Trees can reduce erosion effects by stabilizing soils, shielding soils from erosionary effects of rainfall and the capacity of forests to hold higher volumes of moisture in its soils, thereby reducing the rate of water runoff. Trees can be planted to provide flood protections works, which in many cases offer equal or superior protection than high-cost erosion-control structures. Trees and the shade they provide can considerably ameliorate microclimatic conditions, allowing many other crops and domestic animals to thrive in areas where they would not otherwise thrive.

## Natural forest rehabilitation and reforestation

Forest rehabilitation and reforestation are key climate change adaptation activities that communities can be involved in. The activities are aimed at increasing the quality and quality of forest services being produced from natural forests. From a community and climate change perspective, forest services will include soil and water conservation, water management and the production of commercial timber and non-timber forest products.

There are a diverse range of activities associated with forest rehabilitation and reforestation:

1. Limiting activities such as illegal logging and implementing land-use change such as eradicating slash and burn agriculture. Communities can directly engage in limiting such activities or with support from government and non-government organizations.
2. Fire prevention measures are important for forest protection and rehabilitation. As noted previously, climate change is resulting in many areas becoming either drier or subject to increasingly frequent droughts. These forest lands are increasingly susceptible to deforestation and forest degradation through forest

fire damage. Community-based fire prevention includes changing land use practices (slash and burn), changing land use away from agriculture in selected areas and establishing community-based fire-fighting capabilities.

3. Tree planting and forest silviculture[14] is usually essential to forest rehabilitation and reforestation. Given the uncertainty associated with climate change, it is preferable to maximize the genetic diversity of trees planted through the selection of a wide range of species and selecting seed stock from mixed sources over clonal material.
4. Sustainable forest management for harvesting of timber and non-timber forest products. This is critical because only sustainable forest management can maintain the health of the forest eco-system while generating long-term continuous flow of forest produce.

## Commercial tree plantation development

There is a range of commercial timber species that are grown in tropical and subtropical zones for commercial purposes (table 8.5). Communities often plant these species in small-scale monoculture plantations or integrated into the landscape as part of multiple integrated land uses. The selection of species depends on a variety of factors, including community needs, site and climatic conditions suitability, the general availability of species, community capacity to grow specific species and markets.

Table 8.5: Common tree plantation species grown in the tropics

| Species name | Scientific name | Use of wood |
|---|---|---|
| African mahogany | Khaya senegalensis | Furniture timber |
| Albizia | Paraserianthes falcataria | Light construction, plywood, block board |
| Bamboo | Bambusoideae | Scaffolding, panels, furniture timber |
| Caribbean pine | Pinus caribaea | Structural timber, pulp and paper |
| Eucalyptus | Eucalyptus spp | Structural timber, pulp and paper |
| Gamhar | Gmelina arborea | Furniture timber, pulp and paper |
| Mahogany | Swietenia macrophylla | Furniture timber |
| Obeche | Triplochiton scleroxylon | Furniture timber |
| Rosewood | Dalbergia spp | Furniture timber |
| Sheoak | Casuarina equisetifolia | Structural timber, posts and poles |
| Teak | Tectona grandis | Furniture timber |
| Wattle | Acacia spp | Pulp and paper, furniture timber |

14 Silviculture is the care and cultivation of forest trees.

## Tree planting for non-industrial wood production and livelihoods support

### Fuel wood

In developing countries, wood is the primary source of energy for heating and cooking. For example, in Africa almost 90 per cent of all wood removals are used for energy. With ever higher fuel prices, there will be even more pressure on forests and trees outside forests to provide energy in the poorest countries. In poor rural areas of developing countries, fuel wood is usually obtained directly by felling trees or collecting fallen wood. Recently, recovered woody biomass and residues from logging operations have also become important supply sources.[15]

In the developing world, most fuel wood has traditionally been sourced from natural forests. Fuel wood collection is largely been unregulated and often unsustainable, leading to diminishing fuel wood resources and widespread fuel wood shortages. Uncontrolled conversion of forests to agriculture has often exacerbated fuel wood supply shortages.

The supply of fuel wood can be enhanced through sustainable management of natural forests and establishment of woodlots and plantation forests. The practice of establishing woodlots and small plantations for fuel wood is of relatively recent origin. Highly desirable properties of tree species for domestic firewood plantations are:[16]

- ease of cultivation using simple techniques;
- rapid early growth;
- good survival under adverse conditions;
- resistance to browsing and grazing damage;
- ability to coppice;
- quick drying;
- freedom from smell and spitting when burnt; and
- low ash content.

Development of sustainable fuel wood supplies enables communities to reduce their reliance on diminishing fossil fuels and insulate them

***Firewood***

*Plantation species grown for firewood largely reflect traditional practice, such as:*

- *Calliandra callothyrus in Indonesia*
- *Leucaena leucocephala in the Philippines*
- *Cassia siamea, Eucalyptus camaldulensis and Azadiracta indica in Africa*
- *Dalbergia sissoo in India and Pakistan*
- *Casuarina in Asia*

15 FAO: *State of the world's forests 2007* (Rome, 2007).

16 J. Burley: "Selection of species for fuel wood plantations", in *Proceedings of the 8th World Forestry Congress* (Jakarta, 1978).

against increasing costs. Indeed, firewood is often the only fuel resource that local communities can reliably develop.

## Fodder trees

A common practice in the tropics is to use pruned foliage from trees and shrubs and also to grow trees specifically to provide fodder and browse for domestic animals. Many species are suitable and comprehensive lists have been compiled (table 8.6 lists common species). [17]

Table 8.6: Examples of important timber species grown in the tropics for timber or firewood, and also which are valuable for fodder

| Legumes | |
|---|---|
| Species | Comment |
| Acacia albida | Edible leaves and pods. Suitable for hot arid areas. In leaf during dry season. |
| Acacia arabica | Edible leaves and pods. Also produces gum arabic and tannins from bark. |
| Acacia catechu | Edible leaves from lower branches. Wood makes good charcoal. |
| Acacia seyal | Edible foliage and bark. |
| Albizzia lebbek | Edible leaves. Important shade tree. |
| Cassia siamea | Edible leaves. |
| Cassia fistula | Edible leaves and pods. |
| Dalbergia sissoo | Leaves can be made into silage. |
| Leucaena leucocephala | Edible leaves but toxic in large quantities. Important multipurpose species. |
| Parkia filicoidae | Edible leaves and pods. |
| Prosopis chilensis | Edible leaves and pods. Drought and cold resistant. A good shade tree. |
| Saman samanea | Edible leaves and pods. Excellent shade tree. |
| **Non-Legumes** | |
| Species | Comment |
| Artocarpus heterophyllus | Edible leaves and fruits. Also good human food. |
| Artocarpus indicus | Edible leaves and fruits. Also good human food. |
| Azadiracta indica | Edible fruit can be made into oil seed cake. Arid zone species. |
| Bombax malabaricum | Edible leaves and twigs. |
| Brosimum alicastrum | Edible leaves, seeds, and whole fruits. Fruit edible for humans, latex used for chewing gum. |
| Shorea robusta | Edible leaves, seeds used for fat extraction. |
| Terminalia tormentosa | Branches lopped for fodder. |

Source: J. Evans: *Plantation forestry in the tropics* (Oxford University Press, 1982).

The development of fodder tree resources will enable communities to mitigate impacts of droughts and other climatic events because they can provide alternative feed supplies that are often most resilient to extreme climatic events.

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17 See FAO: *Tropical feeds* (Compiled by B. O. Gohl) (Rome, 1975); FAO: *Forestry for rural communities* (Rome, 1978); A. Jurriaanse: "Are they fodder trees?" (Republic of South Africa, 1973); and H.N. le Houérou: "The role of shrubs and trees in the management of natural grazing lands (with particular reference to protein production)", in *Proceedings of the 8th World Forestry Congress* (Jakarta, 1978).

## Shade trees

Many crops are grown under shade, including coffee, tea, cocoa and some orchards. Some crops, such as cocoa, require shade when young. Other crops (notably coffee and tea) may not be at their most productive under shade, but corresponding smaller demand for nutrients allows a satisfactory crop to be grown with little or no requirement for fertilizers. This is an important consideration for poor communities who do not have the financial resources to afford inorganic fertilizers.

Because of their usually light foliage and nitrogen fixing ability, legumes are often used. Widely planted species include Acacia decurrens, several species of Albizzia, Erythrina, Casuarina and Leucaena leucocephala.

There are several advantages of growing crops under shade:

- all kinds of environmental damage are reduced – wind, hail, intense heat, intense cold, sun-scorch;
- soil erosion is reduced;
- often there is reduction in weed growth, pests and diseases on crops; and
- working conditions under shade are significantly enhanced.

Shade trees directly address and mitigate climatic change impacts by providing protection to crops from impacts of extreme climatic conditions, often protecting against pests and diseases and improving the micro-climatic conditions supporting crop growth and enhancing the working environment.

## Non-timber forest products

The propagation of trees that produce a variety of non-timber forest products (NTFP) benefit communities by diversification of production, protecting them should one or more livelihoods decline or fail as a result of major climatic changes.

The number of tree species grown for NTFP as numerous, and an exhaustive list of these species is beyond the scope of this study. However, the following highlights several important tree species and tree products:

**Rubber**: The rubber tree (Hevea brasiliensis) is primarily grown for the latex it produces, which is used primarily in the production of rubber tyres as well as for numerous other purposes. The annual worldwide natural rubber production is estimated to be close to 8.8 million tonnes. Malaysia, Indonesia and Thailand together produce nearly 80 per cent of the world supply.

An important side product of Hevea rubber production is rubberwood, which was originally perceived merely as a useful by-product for drying and smoking rubber and to provide a source of charcoal for local cooking. Rubberwood can be easily steam-bent or stained to resemble any other timber, depending on consumer demand. Its favourable qualities and light colour make it a good timber for furniture making and other applications.

**Tropical fruit trees**: The number and variety of trees producing edible fruits are too numerous to describe in detail here. Fruit trees often produce durable and valuable timber as a side product, for example, Durian and jackfruit both produce sought-after timber as well as valuable fruiting crops. Several fruit-bearing trees from South-East Asia that also produce timber (table 8.7).

Table 8.7: Fruit-bearing trees from South-East Asia

| Species | Common name |
|---|---|
| Artocarpus altilis | Breadfruit / Sukun |
| Artocarpus champedan | Cempedak |
| Arthocarpus elaticus | Terap / Tarok |
| Artocarpus heterophyllus | Jackfruit / Nangka |
| Aleurites mollucana | Candle nut tree / Kemiri |
| Canarium sp | Pili nut tree / Kenari |
| Durio zibethinis | Durian |
| Garcinia mangostana | Mangosteen / Manggis |
| Lansium domesticum | Duku |
| Mangifera indica | Mango / Mangga |
| Nephelium spp | Rambutan |
| Psidium guajava | Guava / Jambu |
| Sandoricum koetjape | Kecapi |

**Apiculture**: Many tree species support the keeping of bees. Many tropical eucalyptus species, including E. deglupta, E. grandis and E. calmaldulensis, flower profusely and for most of the year and can yield much honey. The Koompassia genera are known as honey trees and naturally distributed throughout much of South-East Asia. This species attracts and supports large numbers of bees and is propagated and protected by many communities for its honey production-supporting attributes.

**Sericulture**: The cultivation of silkworms is widespread in Asia, particularly China, India and Pakistan. Silk worms primarily feed on mulberry leaves (Morus alba), though other species are also suitable, such as Shorea robusta, and can be a profitable industry. The mulberry tree is often planted around fields and canal banks, and trees can also yield cane for basket making, firewood, timber, fodder and edible fruit.

**Tan bark**: Wattle species, particularly Acacia mearnsii, are widely grown for the extraction of tannin from its bark. Wattle also produces quality firewood, is suitable for sawn timber production and is soil enhancing.

## Critical forest management functions

To develop and manage forest lands and tree crops, communities need to have essential forest management skills and infrastructure. These can be broadly broken into the functions of species selection, nursery management, silviculture and sustainable harvest management.

## Species selection

The first problem in a forestry project is often the selection of which species will be actively managed. Species selection influences nursery and silvicultural practices and utilization of the crop. Deciding on species depends on four basic questions:

1. *Will the forest project involve natural forest management or plantation / agro-forestry?*
   Natural forest management by definition usually involves propagation and management of species naturally occurring on the selected sites. Species selection primarily involves propagating trees that accelerate overall forest regeneration and rehabilitation. In many cases, the species actively propagated may only have limited future commercial benefit. Species are often selected because of their abilities to remediate sites and as nursery crops for other natural forest species, which will subsequently naturally regenerate.

2. *What is the intended purpose of the forest project?*
   a. domestic use – fire wood, roundwood for construction and fencing;
   b. industrial uses – fuel wood, pulpwood, sawn timber, etc.;

c. environmental protection – soil and water protection, soil stabilization, wind breaks, and soil rehabilitation; and

d. integrated tree planting for amenity, shade and shelter purposes.

3. *What species are potentially available for planting?*

Once the purpose of a forestry project is known, the choice of species is narrowed considerably. Given the huge number of tree species though, the options available are still huge. There are a number of aspects that need to be considered:

a. Selection of indigenous species. As a general rule, where a native species meets the needs of a project, there is no reason to select an alternative exotic species. The use of indigenous species will not face any political or quarantine problems and there is usually a ready supply of seed and planting stock. Growth of natural stands will often provide some indication of potential growth. Indigenous species are adapted to the local environment and are often less susceptible to serious pests and diseases, as controlling agents are already present. The management and utilization of the species is likely to be known to growers and industry.

b. Selection of exotic species. In the case of plantations, exotics form the majority areas planted, this is especially true in the tropics. Exotic species are often free from their natural pests and diseases and have potential for substantially faster growth. At the same time, exotics are more susceptible to uncontrolled introduction of pests and diseases. Widely planted exotics may benefit from greater levels of research, management knowledge and commercially available support services. While the use of exotics is widespread, not all introductions are successful, and indeed while many species are trialled, often only a few are found to be suitable.

c. Limitations to species selection. Several factors may restrict the use of species that would otherwise be suitable:
   - Seed supply may be limited by biological and political constraints, difficulties in access or communications and lack of seed production capacity.
   - Many promising and desirable species are difficult to replicate in large quantities in nurseries and in the field. The easiest species to grow are colonizers and pioneering species, and these species are often preferred.
   - Some species that have desirable properties and grow well in natural forests do not thrive in closed plantation situations.
   - Some species require high levels of inputs through site preparation and silvicultural management. Where communities have limited financial resources, these inputs may be unaffordable.

4. ***Which species will grow on the sites available?***

Tree species must be well matched to the site to thrive. Site and species matching is of little importance to indigenous species growing in or near the planting area but is of highest importance in plantation and agroforestry projects. Key site variables are:

a. **Climate.** Climatic variables are the total and distribution of rainfall and the temperature range. Climate change increases the variability of climatic conditions and may dramatically impact on associated species selection.

b. **Soil.** Factors are soil depth, physical structure, drainage, fertility and other chemical properties, such as acidity and toxicity levels. Soil properties are critical for all species. Silviculture can improve site suitability through cultivation and fertilization and are often essential for many species.

c. **Existing vegetation cover.** Some species require land to be completely cleared of competing vegetation prior to planting; for example, Eucalyptus species usually do not tolerate competition from grasses. Other species can tolerate competing vegetation and can be interplanted, such as Swietenia macrophylla. A select range of tree species actually require a nurse crop or shelter to establish itself.

Other important factors to species selection:

a. **Susceptibility to flooding.** A few select species, such as Eucalyptus robusta, are tolerant of prolonged flooding.

b. **Fire resistance.** Some species are naturally resistant to fire and can be planted as fire breaks. Other species such a Pinus caribaea and Tectona grandis recover well from fire and may be preferred on high fire susceptible sites.

The selection of species involves gathering information on local conditions, existing forest management practice and experience and implementation of trials. Short-term results of trials may be misleading, however, because they usually only indicate how easily species can be established and not their long-term viability.

## Planting material supply

There are three main types of planting materials routinely used for forestry projects. First, tree stocks can be grown from seed and this is the most common source of planting materials. Seed can be collected from unimproved locally grown trees and these often have the benefit of being adapted to local conditions. In many cases, provenances have been identified that provide superior properties for specific purposes. Reputable suppliers can provide seed that is certified in terms of source and provenance who usually provide a statement of testing and seed quality. Seed collection and storage techniques vary widely, but commonly involve:

- seed collection through ground collection, direct gathering through climbing or de-limbing, or collection from felled trees.
- seed extraction and cleaning.
- seed storage.

Second, tree stocks can be vegetatively propagated by the taking of live samples from a parent plant and then inducing rooting on the live sample. Live samples can be taken from leaves, stem, and roots.

Third, seedlings can be directly collected from existing forest areas. This is often necessary for species that seed sporadically or which cannot practically grown from seed.

## Nursery management

There is a huge variety of nurseries, both in terms of design and scale. The requirement for nurseries demonstrates a key difference between forestry and agriculture. In most agriculture, seeds are directly planted in the field. In most forestry, seedlings are produced in nurseries and then planted out in the field.

Nurseries can be temporarily established, usually close to the planting sites or permanently based in one location to supply large numbers of seedling over a long period. The main requirements for a nursery are:

- good access to and within the nursery;
- continuous water supply;
- ready access to labour supply;
- protected from persistent wind, hail and other extreme weather; and
- for open grown nurseries, soils should be workable, free draining and have good texture; heavy clays are normally not suitable.

Nurseries can either be grown in open seed beds or in some sort of container or root trainer vessel. Open-grown nurseries are often cheaper to establish and operate but are more susceptible to diseases and weeds.

The actual design and management of nurseries are dependent on the methodologies required to propagate the planting stock and the scale and timing of planting operations. The main operations are fairly standard throughout all nurseries:

- planning; this is particularly critical for the nurseries where planting stock supply is often very tightly linked to external land development operations;
- seed storage and treatment;
- soil preparation of seed beds or containers;
- fertilizer preparation;
- sowing seed or cuttings preparation;
- planting stock maintenance;
- weed control;
- protection against damage from the climate, pests and diseases; and
- packaging and dispatch.

## General silviculture operations

Silviculture is the practice of controlling the establishment, growth, composition, health and quality of forests to meet diverse needs and values of the many landowners, societies and cultures. An in-depth discussion of silvicultural practices is beyond the scope of this guide, but the basic operations are described below.

**Pre-establishment**: Prior to any planting operations, legal access to land and operations boundaries must be determined.

**Site preparation**: The extent and intensity of site preparation depends first on the ability of the selected species to establish themselves, compete with other weeds and vegetation, the soil structure and vegetation-cover conditions. Site conditions that aid tree establishment include weed control and soil cultivation. In some cases, earthworks will be required to improve the draining characteristics of the site.

**Establishment**: Throughout the tropics, planting is usually planned to coincide with the wet season. A range of planting techniques are available, including direct seeding, hand planting and mechanical planting. The planting pattern and spacing determines the initial stocking, and the selected stocking rate should make allowances for tree mortality.

**Maintenance**: The silvicultural operations required between planting to harvesting are dependent on the species being managed, the local site conditions and the management objectives for the forests.

Trees are often most vulnerable at the juvenile stage, and it is common to conduct intensive protective operations in the months following planting. These can include watering, weed control, fertilizer application, protection from pests and browsing and replanting of dead planting stock.

The common silvicultural operations during the post-establishment are:

- **Thinning**. High initial planting densities are often adopted to insure against natural mortality, induce height growth and inhibit branching. As a result, trees need to be removed mid-rotation to remove competing trees, stimulate further growth and sometimes generate intermediate yields. Thinning allows residual trees to grow and occupy additional growing "space" and can stimulate growth of individual trees.
- **Pruning**. This is the removal of lower branches on trees. It is done to: i) provide access into the forest, ii) reduce fire hazard, iii) facilitate felling and extraction of thinnings; and iv) produce know free timber at the base of the tree thereby improving the value of the tree crop.
- **Fertilizer application**. Fertilizer is used in forests in three situations: i) to correct for nutrient deficiencies; ii) to establish lands on otherwise impoverished or unplantable land; and iii) to stimulate additional growth. The distinction between these is not precise may be done for multiple purposes.

## Afforestation on inhospitable sites

Reforestation and protection forestry are commonly conducted on sites that are initially inhospitable to forest establishment. Sites are made inhospitable by extremes of climate (dry, persistent wind, cold), soil condition (thin or rocky soils, nutritional problems, soil instability, compaction, soil hardness and poor drainage) and damage from animals and fire. Climate change is by definition the increase in the frequency of extreme conditions that create these inhospitable sites.

In practice, there are few sites where trees cannot be grown outside of deserts, extremely cold areas in arctic areas and at altitude and on rocky outcrops. The main challenge is to ameliorate inhospitable sites sufficiently to allow trees to grow. Once vegetation cover is established, trees create micro-site conditions that are more hospitable to further tree growth and other land uses. The tree canopies provide shelter from the weather, the tree roots systems stabilize soils and the forest ecosystem conserves and recycles biomass, nutrients and moisture, thereby improving soil conditions.

Afforestation on inhospitable sites requires special management, focusing on three primary elements:

- **Species selection**: Inhospitable sites may be unsuitable for the establishment of most utilizable tree species. However, there are a select group of pioneer species that tolerate cold, dry or exposed conditions, or on unstable, hard, infertile or toxic soils. Some of these species offer only limited or temporary cover but sufficiently ameliorate the site to allow the establishment of other tree species.

  Many Acacia and Eucalyptus species are drought resistant and used in reforestation of arid sites. Containerized stock is preferred on arid sites because a ball of soil comes with the roots, providing some moisture and nutrients to support initial survival. Other species that grow well in dry sites include Azadiracta indica (Neem), Cassia siamea, Casuarina equisetifolia, several species of Prosopis and Leucaena leucocephala.

- **Site modification**: Modification of the site can significantly improve surface stability, water relations and nutritional status. In arid areas, the main aim of site modification is to trap all available moisture and reduce water losses and direct moisture to the trees. This can be done in several ways including fish bone cultivation which directs surface water to the trees, ripping the soil to break hard pans and improve tree access to sub-soil moisture, and in some cases through irrigation. Soil can be cultivated improving root penetration and access to roots and nutrients although care needs to be taken not to increase moisture loss or soil instability. In some cases, physical barriers such as fences, ditches and shades may be required to block wind, water flows, or provide shade sufficiently to enable trees to survive.

- **Rigorous protection measures to minimize damage**: Rigorous protection of young trees for the first few years is especially important on inhospitable sites. Pressures from grazing are often very high and stock can rapidly decimate large areas of young trees. One effective method for excluding stock and provide some shelter is to plant hedges. Most effective species are resistant to browsing and are often spiny.





## Planting layout and integrated land use

For community-based forestry, tree planting is rarely done over whole catchments. Tree planting needs to be strategically planned and integrated with other land uses and the overall landscape. The objectives and implementation modes can include:

- establishing trees on inhospitable sites unsuitable for agriculture;
- tree planting to stabilize erosion or flood prone areas;
- establishing tree shelter around pasture and crop lands primarily for wind protection;
- establishing trees within pasture and crop lands for wind protection, shade, soil stability, nutrient recycling, fodder, etc.;
- establishing woodlots for domestic and commercial purposes; and
- rehabilitation of natural forest areas to improve forest related livelihoods, wildlife conservation and management, soil and water protection.

A wide variety of systems have been described for integrated forestry and agriculture and are known by many names such as agroforestry, farm forestry, tree farming, three dimensional forestry, etc. The following summarizes a range of systems:

- **Woodlots**: Whether planted or natural, woodlots fulfil two important needs in addition to protection and shelter. They are a source of fuel and construction materials. In areas devoid of trees, the establishment of woodlots is potentially a very effective means of raising rural living standards.
- **Intercropping**: This is the practice of growing crops between rows of trees. This is widely practised at both an individual land holder level and in some cases by large-scale commercial operators. Intercropping allows the simultaneous development of a wider range of products and services in a given area. In some cases, the inter-planting of trees and crops may actually increase the productively of the land uses because of synergies between the crops. The "taungya" system is a well-known version of intercropping, conducted for several years in one location, after which time the cropping is abandoned and the trees are left to grow. The taungya system allows the development of forest resources and improved land use but does not require radical changes to traditional shifting cultivation practices.
- **Sequential cropping**: This is the practice of growing one crop after another in short succession. In tropical plantation forestry, crops are often grown between planting of successive plantations. In many cases, crops are also grown after

trees have been planted up to canopy closure (generally two to three years following planting).

- **Forest grazing**: Domestic animals can be used to graze grass, browse herbs and shrubs growing under trees. In addition to providing a source of feed, forest grazing can substantially decrease fire hazard. The forage quality of forest vegetation is generally poor compared to pasture, but this is partially mitigated by the shelter given to stock under the trees. Animals need to be carefully managed to minimize tree damage and, generally speaking, forest grazing should not be conducted until trees are over 3 metres in height. Sheep are especially suitable for forest grazing and have been widely used for grazing in rubber and coffee plantations. Cattle can sometimes damage larger trees by leaning on them. Goats are not generally recommended for forest grazing because of their tendency to damage the bark of trees.

## Using a local resource-based approach: examples of ILO work

The failures of the centralized resource forestry management approaches have been widely acknowledged. The main reasons behind their failure have been the vast size of the forest areas, limited financial resources and administrative, technological and enforcement capacities of the states, corruption, insufficient information concerning forest ecosystems and the failure to recognize customary rights to land.

Consequently, governments have increasingly started to look for decentralized, local level management models, which would enhance sustainable resource management and support local development. Decentralization has also been strengthened by the increasing recognition of indigenous and other local communities' rights to the lands they have traditionally managed. Decentralization in forest management is part of the general trend towards more decentralized decision making and increased local participation. In relation to natural resources, decentralization encompasses the transfer of authority over natural resources decision making from the central government to local governments or administrative units and to non-state local actors.

Recently, collaborative forest management has been introduced on a larger scale in many countries. This is reflected in the national forest policies of these countries emphasizing devolution of forest management by involving people's active participation. Collaborative management has been termed variously as joint forest management (such as in India), community forest management (such as in Nepal) or participatory management. This broadly defines the practice as sharing of products, responsibilities, control and decision-making authority over forest land between governmental forest departments and local user groups, based on a formal agreement.

Experience has shown that participatory forest management is capable of reversing the trend of forest degradation. Therefore, the various approaches of participatory management have come to be recognized as an important strategy for attaining the objectives of sustainable forest management.

The earliest ILO involvement in forestry dates back to a project in West Bengal (1976). In the period 1980–1981, ILO forestry programmes with a total of about US$9 million were approved. Most of the projects had multiple objectives. The first generation of projects started in the early 1980s for a typical duration of three years but these projects were extended to five or six years in order to bring the projects to a degree of completion not originally envisaged. A typical cycle included nursery and plantation work, replanting, initial maintenance and protection. Reasons for the extension of the duration of the projects related to an under-estimation of the complexity of the site management and organization and an over-estimation of the capacities of the governments to take over the projects.

In general, none of the projects experienced shortages in labour availability. In some cases, job rotation was introduced to cope with the large numbers of labourers who had expressed interest to work on the project.

In general, the projects achieved their output targets, or sometimes even exceeded them. Cost-comparisons with equipment-intensive approaches demonstrated the cost-effectiveness of the labour-based approaches that were followed.

Maintenance issues were addressed successfully in a number of forestry projects. This was because of the longer duration of the project and/or initiatives by local communities. In general it was found that the forestry departments were unable to assume post-project responsibilities. At the same time, some reluctance was noticed of delegating responsibilities to the local communities, even in return for a share in the proceeds.

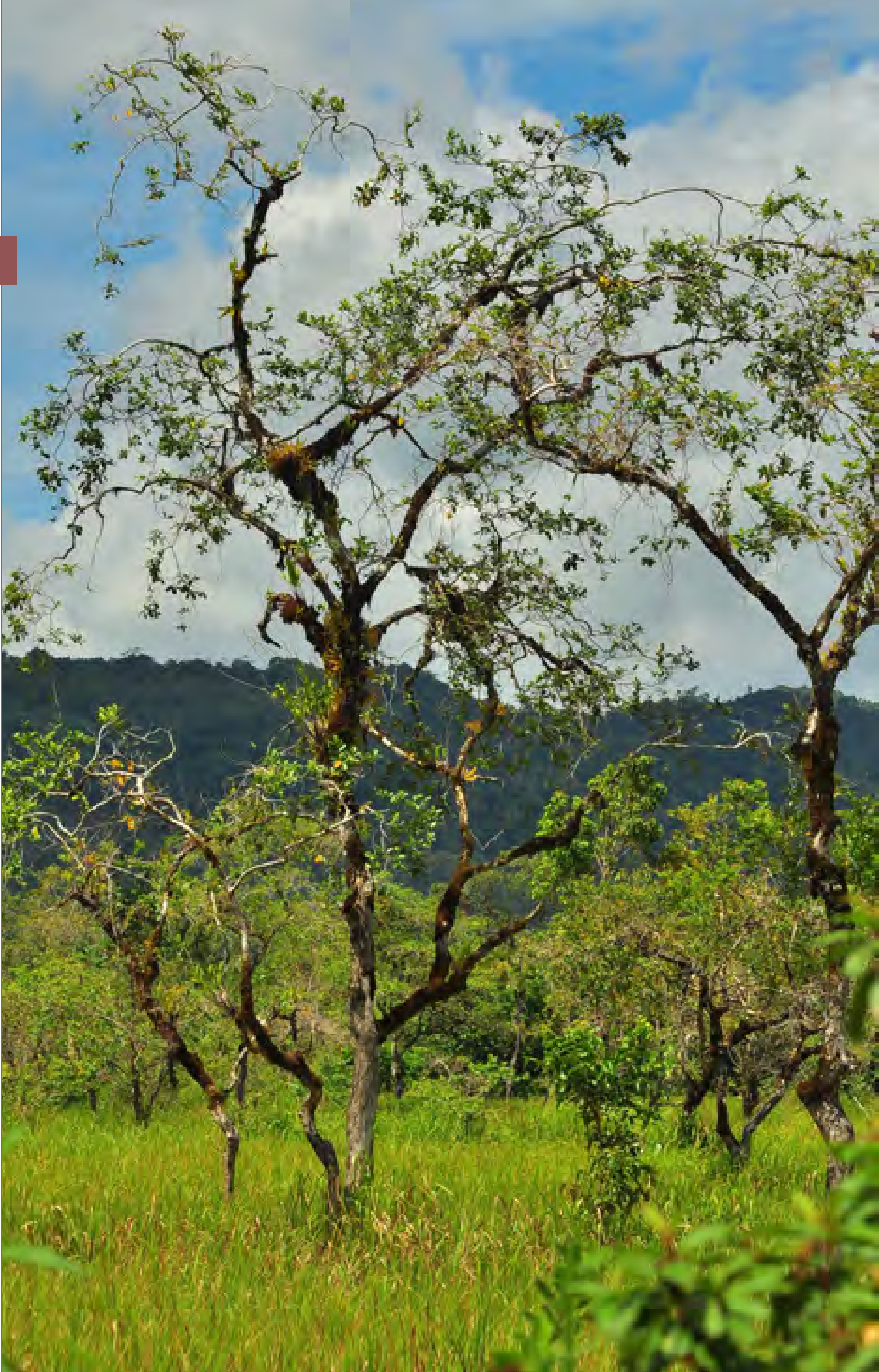
***ILO forestry and soil conversation activities***

*In 1987, a review of the ILO forestry and soil conservation activities in 11 countries covering the period 1980–1986 was undertaken. Outputs of interventions included the protection of 70,000 hectares of forests, the plantation of 11,000 hectares of new forests and the rehabilitation of hurricane-damaged forests, and the production of 17 million seedlings. Labour expenditures accounted for 64 per cent of the total expenditures and more than 3 million labour days of paid work were generated through the various projects. Compared to the infrastructure sectors, the labour-intensity in forestry is considerably higher. Employment opportunities provided by the projects were eagerly sought after by the rural poor, and a job rotation system was successfully introduced to ensure one of the main ILO principles – equal opportunities for access to work. The evaluation also found that the projects' labour-intensive approaches had been more cost-effective than capital-intensive approaches in similar projects.*

Whereas the first generation of ILO forestry and soil conservation projects were of the classic public works type, later projects embraced the concept of diffusing forestry activities into smaller units and towards an integration of forestry and soil conservation practices into household, farming and agricultural systems. This evolution led to an increasing focus on long-term employment creation and an improvement in the living conditions of the targeted beneficiaries.

One of the lessons learned is that forestry projects have a long gestation period (10–20 years) before they reach their full benefits. Consequently, long-term external assistance commitments are required. Projects should also take more account of the use that is to be made of the created wood resources. Where required, technical assistance for harvesting and marketing of forest products should be initiated at an early phase of the project.

Another finding was that forestry projects often conflict with farmers' short-term



economic interests of cultivating land with (cash) crops that provide short-term returns. It is equally important that during the project formulation phase, adequate maintenance arrangements are made to ensure the long-term sustainability of the activity, especially when activities are being scaled up.[18] It is also necessary that long-term benefits are already agreed upon during formulation.

Experiences also indicate that agro-forestry and forests that produce a variety of products and services (regulation of water flow) may be more sustainable, provided that the local population is supportive and that these projects are technically well planned. Multipurpose forests have the advantage that they provide a quicker and more continuous flow of benefits, spread benefits over a larger proportion of the population, and produce synergetic effects, with one activity increasing the productivity of the other.

The need to involve the local people throughout the different steps of the project cycle, including the formulation of the project activities, also requires a sufficiently long project preparation or inception period. Experiences indicate that 12–18 months may be required to ensure a proper project preparation.

***Forest exploitation that contributes to preservation and self-employment in Mali***

*In Mali, the EIIP-supported Management of Forest Resources in the Kita District project developed a contractual approach to provide villagers living adjacent to the forest access to forest resources. The project started in 1990 and was completed in 1997 focused on 5 classified forests with a total area of 90,000 hectares. These forests were surrounded by 35 villages, with a total population of about 20,000 people. The project's main objectives were to create sustainable employment and income, promote social organization and contribute to preserving the area's natural resources.*

*The introduction of the contractual and participatory approach took advantage of the political climate and administrative changes underway at that time in Mali's forestry sector. The approach of this demonstration project proved to be very effective and successful. It resulted in the acceptance of the developed contractual approach at the national level and the integration of the model into the country's forestry legislation. The developed model has enabled the establishment of a method of forest exploitation that contributes to rural self-employment and to the preservation of forest resources.*

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18 In general, it is recommended that new forestry initiatives start at small-scale so as to test techniques, to gauge the response of the villagers and to adjust the project as required. An area of around 5 hectares is considered a good beginning for village afforestation on communal land. Planting on a larger scale should not be increased before a village commitment has been obtained.

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9

# Summary

# Summary

## 9.1 The reality of climate change

Climates throughout the world are changing as a result of heating caused by the greenhouse effect. Human-induced gasses, including carbon dioxide and methane, have been released into the atmosphere and are causing a greater proportion of the sun's heat to be retained. The change is not uniform throughout the world, but the increase in temperature is causing major changes to the climate. In some areas, these result in longer periods of drought. In others they lead to greater and more intense rainfall. Melting of ice caps is leading to an increase in sea levels. An increase in extreme weather events, such as typhoons and major storms, is leading to increased loss of life and damage to infrastructure.

Countries in the Asia-Pacific region are particularly at risk and are already experiencing increased flooding in all areas, including South Asia and China.

Global response to climate change includes two separate activities. First is mitigation, whereby the increase in such gasses can be slowed, stopped and even reversed. Second is adaptation, the task of ensuring that infrastructure, agriculture and other human activities are better able to withstand the damaging effects of climate change.

## 9.2 Climate change and the poor

The poorest are inevitably most at risk from climate change. For many, life is already a constant struggle and climate change is already impacting on them. As the effects

of climate change increase, they will suffer most of all. Most of the rural poor practice subsistence agriculture and already have very little food surplus to cushion against adversity. Changes in the rainfall pattern mean that there may be flooding in the fields at certain times of the year and shortages of water at others. Erosion and other soil degradation are likely to increase. Decreases in crop yields and in the cultivable land will lead, inevitably, to food shortages, malnourishment and even starvation.

Increased flooding will make it harder for the poor to access clinics, schools and markets. This will lead, in turn, to poorer health and greater school absenteeism. With more time being spent on domestic tasks around the home, such as gathering fuel wood and collecting drinking water, girls may be needed at home more and this may lead to lower female attendance at school. Less access to markets makes it harder to buy the essentials of life and to farmers being unable to sell their own limited surpluses. Taken together, these will have a major impact on affected communities.

Poor communities must be empowered to adapt to climate change. As well as being provided with the physical tools to do this, they must also be made aware of the impacts of climate change and helped to use planning and other local resource-based techniques to deal effectively with them. Flooding needs to be seen as part of the recurring circle of life, and communities must be able to deal with it, without assuming that the government will always deal with problems when they arise.

## 9.3 Adaptation through infrastructure and public works

### Irrigation

Irrigation, the controlled application of water to arable land, is important for all countries in the Asia-Pacific region. With 60 per cent of the population relying on agriculture for their livelihoods, irrigation has a direct impact on the lives of many of the poorest in the region. As 34 per cent of the land in the region is irrigated, failure to deal effectively with the challenges of climate change will lead to increased hunger and possibly famine.

Climate change will lead to higher average temperatures in the region. Some areas will experience higher rainfall while others will experience lower rainfall with longer periods of drought. In both, there will be a tendency to increased intensity of rainfall, leading to a greater proportion of it being lost as runoff. Glacier melt will lead to higher water availability in the short term but ultimately to reductions in river flow. Higher evapotranspiration and lower soil moisture levels will also lead to greater demand for irrigation water. Agricultural yields will fall, leading to a need to bring greater areas under cultivation and irrigation. Overall, irrigation requirements are expected to increase by 15 per cent by 2020 in the region. The increase in variability of precipitation will necessitate the extension of irrigation into areas that have relied on rainfed irrigation in the past. Irrigation is not the only user of water, and the increase in demand for water from other sectors will lead to increased water stress in certain areas.

There will be an overall need for an expansion in the irrigated area, both in terms of large new systems and also in terms of small systems where land that was exclusively rainfed receives irrigation during drought. Improved storage such as small dams, ponds and groundwater recharge within existing systems will be critically important so that the rainwater that does fall can be retained for later use. Improving the retention capacity will be important to reduce runoff. The flooding noted elsewhere will damage both irrigation infrastructure and the crops themselves. Irrigation systems will need to be adapted so that they are less susceptible to such damage. Improved irrigation efficiency will be essential, with a reduction of losses in various parts of the system. This can be achieved by improvements to parts of the infrastructure and also by improvements to irrigation methods in the fields. Better system management and farmer education are essential part of this.

The local resource-based approach introduced in this guide applies equally to irrigation. Where water users' associations already exist, they should be the main channel for such support. They are often in the best position to know what the effects have been, even if they lack a scientific understanding of it. Integrated planning, taking into account all water use, must be undertaken. The building of small dams and reservoirs follows the well-established principles of labour-based construction. New or improved canals are also suitable for labour-based approaches and for the use of community contracting or small contractors.

## Soil and water conservation measures

Loss of soil through erosion is one of the most important forms of soil degradation. This leads to declining agricultural productivity and to reduced livelihood opportunities. It can be caused by the action of both water and wind. As a general rule, the greater the intensity of rainfall, the greater its ability to erode soil through increased runoff and other effects. The increase in erosion can be more than double the increase in rainfall. The greater frequency of extreme weather events will also contribute to increased erosion. Wind erosion is expected to increase in areas where annual rainfall is expected to decrease. This will be most marked in Central Asia, but other parts of the region will also suffer. In addition to the immediate problems for the farmers, increased erosion can also lead to increased sedimentation downstream.

Improved soil and water conservation measures will be required to reduce loss of water and erosion. The most immediately relevant are the use of vegetative and soil management methods by the farmers. Where these are insufficient, field-level physical measures aimed at reducing the slope, such as contour banks, contour trenches and terraces, may be necessary. Diversion ditches and waterways may be needed to guide excess water safely away from the field. Check dams in waterways and gullies can slow down the water flow and can vary from bamboo to larger gabion structures. Small dams can be used to harvest water and percolation ponds to recharge aquifers. Subsurface dams can stop the flow of groundwater and make it available for a longer period. River bank protection and river training may also be used.

Vegetative and soil management methods have the advantage that they are applied at field level and require no agreement with neighbouring farmers. The increased erosion induced by climate change is likely to lead to greater use of physical methods. Contour banks and trenches can be applied at field level, but where the fields are small and fragmented they can cover several farmers' land. Gully erosion will also become more frequent. As the need for physical methods increases, this takes farmers from a situation where they are able to deal with a problem themselves and into one where community action is required. Outside support is often needed at this point to support community decision-making and participatory planning. The use of community mapping during participatory planning is important to identify soil and water conservation activities, especially where these are of a physical nature.

## Flood control

People have lived on flood planes since earliest times, and periodic flooding has been a fact of life for many. With increasing population pressure and urbanization people no longer have the option of moving out of the way of flooding. Flood protection measures, such as dykes and river wall protection, have become common alongside rivers. Not all are well designed or built. Climate change has already led to greater peak flows of water in rivers, and the situation will get worse. If an earth dyke is overtopped, there is always the danger of rapid catastrophic breach and collapse with considerable loss of life.

A key issue in the development of new or higher flood protection works is that the scheme must not simply move the problem further downstream, leading to the flooding of areas that had not previously flooded. New schemes must also be designed to be fail-safe so that overtopping does not lead to collapse but to the controlled flooding of an area already identified as suitable.

Even low-level, non-catastrophic flooding impacts on urban and rural living conditions, health, livelihoods and transport. In urban informal slum settlements, where natural drainage has often been blocked, it makes life miserable and unhealthy. Malaria and other water-related disease becomes a major problem. In rural areas schools, clinics and markets in adjacent villages can become inaccessible. It also becomes much harder to reach the nearest all-weather road.

Rising sea levels are another challenge in low-lying areas, such as Bangladesh and Viet Nam. As well as occasional inundation during high winds and tides, this leads to salinization of the land and of groundwater. Building sea dykes can help to mitigate the impact of such rises, although in many areas they are not a long-term solution.

The construction of dykes and sea dykes, storm drainage, river training and bank protection, channel improvement, flood refuges and the raising of homes and even whole villages are solutions that are suited to local resource-based approaches. Community-based planning must be used to identify what is the problem and what are possible solutions in a particular location. The use of local resource-based approaches, including community contracting, the use of gabions, labour-based techniques for the construction of dykes and other embankments are all well suited to these situations.

## Rural transport

Effective connections are essential for rural areas. This includes roads, paths and, where appropriate, waterways. Within villages, most transport is on foot and includes the inhabitants going about everyday tasks, including the collection of drinking water and firewood. Access to services such as education and clinics all involve movement along paths or roads. The fields must be accessed from the houses and agricultural produce must be taken out of the field and to market.

At its most basic, the effect of climate change will lead to roads and both local and inter-community paths being flooded more frequently. This will impact on mobility and on accessibility to goods and services. The greater intensity of rain expected will lead to unsurfaced roads being in worse condition than in the past and to their deteriorating more quickly. Roads in flat areas are most at risk from simple flooding, while roads in mountain areas will be more at risk of damage from the action of rapidly flowing water in the drains and in cross streams. Both would lead to communities becoming inaccessible or to journeys taking much longer because a different route is necessary. At the very least, this would lead to problems in taking crops to market and stopping agricultural inputs coming into the village. It will also lead to fewer visits being made to clinics by all sections of the community, including pregnant mothers, and to increased absenteeism from school. Even the collection of safe drinking water will become more difficult. The impact would inevitably be greatest on women and girls, who may already spend much of their time collecting water and firewood.

Where a section of road or path in a flat area regularly floods, consideration must be given to raising it. Regular use of four-wheel drive vehicles on waterlogged roads causes major damage and must be avoided. Local-based planning to identify priorities within communities can be carried out using planning tools, such as IRAP. Future rises in water levels must also be taken into account when calculating how much a road or path should be raised.

The raising of such roads and paths is a straightforward solution to the problem, provided thought is given to sufficient culverts and other cross drainage to permit water to drain away. The planning and design of new rural roads and paths must also to take into account likely future climate change. Current good practice must be followed, but with account being taken of future rainfall and flood levels. Where possible, consideration should be given to combining transport and flood control benefits from a raised road embankment. Where a new raised path is being built, it may be sensible to pave it to protect it from heavy rain so that bicycles and motorcycles can use it in all weather. The building of new footbridges along such raised paths will be important and is within the capacity of communities, provided they receive adequate support.

Rural roads are seldom adequately maintained. With heavier and more intense rainfall arising from climate change, routine maintenance will become even more important to ensure that drains are kept clear and problems dealt with quickly. Greater competition for limited resources means that communities may have to take action themselves to ensure that their road remains open.  Climate change will have an impact on rural transport services that are already under considerable strain from lack of both investment and maintenance. Failure to stop flooding may lead to operators curtailing services.

In deltas and areas such as large lakes, the use of boats is an important part of the local transport network. The building of new, higher and stronger jetties enables communities to adapt to their particular climate change challenges.

## Forestry

Forests are one of the world's most important natural resources providing many benefits, including industrial wood and non-wood products. They also contribute to water supply, protect soils and fisheries, and protect against flood and drought. They contribute to biodiversity and are available for recreation. They are economically important providing 10 per cent of GDP in some of the poorest countries. Around 1.6 billion people rely on forests to some extent for their livelihoods. This includes 60 million indigenous people who are fully dependent on them and 350 million who live in or near them and are largely dependent on them for their livelihoods and shelter.

The world's forests are under pressure. Almost 13 million hectares are being destroyed each year, and developing countries represent a particular problem. Deforestation has many negative impacts, including undesirable climate change. Forests are a natural store of carbon, and changes in climate will lead to further degradation of existing forests by a number of mechanisms. The increased rainfall intensities and flash flooding will have considerable impact and could be important factors in forest degradation.

Forestry and related activities have the potential to mitigate climate change. This can be achieved by reforestation, improved land and forest management and reducing emissions from deforestation. This can include the planting of trees at the local level, which offers many benefits, including improved nutrition, cash crops and fuel wood.

Adaptation to climate change is a complex process requiring knowledge of the change process itself, together with the effects of land use changes. Adaptive policy in government and clear related legal frameworks need to be developed if adaptation is to be effective. The role of communities in successful mitigation and adaptation will be fundamentally important. They must be encouraged to stop unsustainable practices and replace these with long-term sustainable alternative livelihoods. For this to be successful, communities must be consulted, co-opted into the planning process and engaged in implementation. Community forest management is a well-tried approach that can address the problems of ineffective and corrupt centralized forest management.

Support for community forest management is similar in principle to other local resource-based approaches described in this manual. Experience to date has shown the importance of political commitment, understanding of community needs, appropriate incentives and an approach to planning that takes into account the particular needs of the individual communities. Community forestry groups can be used as the focus for green jobs in adaptation, including the planting of seedlings and other activities to promote reforestation in existing forest areas. The planting of new forests must be undertaken with care and after an environmental impact assessment. Where new forests are planted, the production and planting of seedlings, together with other works, offers ideal opportunities for the use of community contracting and other local resource-based approaches.

Where there are no existing forestry groups, communities can be empowered to organize themselves to carry out interventions using local resources to adapt to the impact of future weather events. This could include the planting of mangroves along the seashore to limit the impact of increased storms. The planting of trees along roads and footpaths is another suitable activity for communities. The planting of suitable grasses and other plants along embankments as part of bioengineering activities can help to stabilize slopes that are more at risk from the increased intensity of rainfall being experienced because of climate change.

## 9.4 Optimizing the benefits by using local resources

Infrastructure, in the form of rural roads and paths, irrigation and flood prevention schemes, is essential to the lives and livelihoods of the poor. There must be considerable public investment in the extension and adaptation of such infrastructure if the impact of climate change on communities is to be mitigated. The earlier chapters described local resource-based solutions in dealing with the impact of climate change on irrigation, soil and water conservation, flood control, rural transport and forestry. Local solutions to deal with local problems are an inherently more sustainable approach.

Increases in flood levels can affect or threaten much of the local infrastructure, and remedial action will be necessary. This may be as simple as raising the height of a road or path and adding more cross drainage structures so that it remains open during periods of flooding. It could involve raising and strengthening dykes alongside rivers so that an area is either not flooded or is flooded in a more controlled manner. It could

also involve making physical changes to irrigation schemes to overcome the danger of damage to both the scheme itself and to the crops growing in it.

Changes in the rainfall pattern may lead to periods of drought and to greater intensity of the rain that does fall. This will call for changes to irrigation practice and more field and local-level anti-erosion activities. It could entail building small dams and ponds so that the water is available for use over a longer period. It could involve building a percolation pond so that water that would otherwise run off enters an aquifer and is stored for later use. It is important to see such infrastructure in an integrated manner. If a new or raised road or path also acts as a floodwall, then it will be doubly useful.

It is clear that the challenges of climate change will lead to communities needing to take and prioritize decisions relating to local infrastructure on their own and organizing implementation themselves. Few communities have this capacity, and the great majority need support in the establishment of community groups to identify what needs to be done and how they should set about it. Existing groups for irrigation or forestry can sometimes be used as the basis for new groups or the role of the existing group can be extended. The establishment of such groups requires the use of community organizers in the first instance to ensure agreements are reached with the consent of all, not just the more powerful groups in the community.

Where funding is available for work, it is important that the use of local resource-based approaches is agreed on as soon as possible in the design process. This will ensure that the work is designed to maximize the use of embankments and structures that can be built using local materials. Construction techniques must be adopted that facilitate the use of community contracting. Community contracting is particularly useful because it provides paid work in the community and avoids many of the drawbacks inherent in using small contractors. Community contracting is well suited to the local resource-based approach because most of the earthworks and gabion structures are relatively simple. Local contractors can still be used for slightly more complex works, such as masonry and reinforced concrete.

Working together to deal with a common problem has been shown to empower communities. If done effectively, it can overcome the sense of being powerless and give them the confidence to deal with future problems on their own or, at the least, with less support from government.

The importance of credible and robust arrangements for maintenance has been a recurring theme throughout this manual. It is even more important for local resource-based infrastructure than for more conventional structures. The organization of maintenance through local enterprises or community groups contracted specifically for this purpose has been found to give much better results than voluntary labour contributions. This is equally true for irrigation and drainage structures, paths and rural roads. The use of individuals or small groups trained and specifically responsible for clearly defined tasks on sections of road, irrigation channels, dykes and river training has been shown to be very effective. Part of their duties should always be to report anything that is beyond their capacity to repair and in need of urgent remedial action. Paying for maintenance can also lead to the creation of sustainable jobs in communities.

In summary, whether undertaking climate change-related work identified by the community, work paid for by a donor or as maintenance, a local resource-based approach is often the best solution and will help to optimize benefits to the community. This must start with facilitated community-level mobilization, during which the community establishes a user or working group and committees with clear responsibilities. The groups so formed then take responsibility for the work that is to be done and, where appropriate, for future maintenance. The community is helped to identify for itself the cause of the problem and what action is needed to overcome it. Most communities welcome the opportunity to do paid work, especially if they feel it is shared equitably, and the poorest households must be given an opportunity to work. The community must be shown the benefits of avoiding the use of expensive materials that must be brought to the site, such as cement and steel reinforcement. The use of local fill and other material suited to the limited skills of the community must be encouraged. Involvement of communities and water users' associations during construction and rehabilitation usually increases the sense of ownership and creates the necessary skills for the implementation of proper maintenance.

## 9.5 Conclusions

The techniques included in this manual include approaches to many of the practical problems facing urban and rural communities. They offer a menu of opportunities to provide green jobs in meeting the challenge of climate change. Donors and national governments must find the funding to help poor communities to adapt to climate change in ways that will strengthen them and, where possible, provide paid work for the communities.

The message of this manual can be summed up as follows:

- Climate change contributes to poverty and vulnerability in many ways.
- Local communities must be empowered to adapt to climate change.
- Infrastructure and public works must be seen as part of the adaptation process (irrigation, soil and water conservation, flood protection, sustainable rural transport, and forestation).
- Public investments in these sectors must seek to optimize the use of local resources to maximize benefits to the rural poor and vulnerable.

## Local investments for climate change adaptation

This guide introduces an approach for infrastructure development and public works in the context of climate change adaptation. It links adaptation with poverty reduction and employment creation. It introduces a local resource-based approach and demonstrates how green jobs can be created through green works.

In developing countries, it will be the poor who suffer the most from the changing weather patterns. People in different parts of the Asia-Pacific region will be affected in different ways. Climate change will impact on their livelihoods, living conditions, water supplies, flood risks, health and transport. People will adapt by changing their habitats, behaviour and livelihood activities. Local infrastructure and public works management will need to make a major contribution in the adaptation responses to climate change.

There are three main areas for local infrastructure and public works adaptation. The first is irrigation and water and land resource management in rural areas so that the variability and intensity of water can be controlled and the quality of existing land can be improved. This includes community forestry. The second is flood control, protection and drainage and water conservation structures in both rural and urban areas, which will need to be designed to deal with the variability and frequency of water availability. The third is rural transport, especially rural roads, which need to be improved and maintained to withstand the increased level of rainfall and flooding.

The ILO has developed a range of tools that can be used in the planning, preparing and implementing of these necessary responses. Guidelines and training manuals are on hand for building up capacities as well as local infrastructure and public works. These types of activities traditionally have taken place within the context of rural development, urban low-income settlement upgrading and crisis response. There is a need now to set this work in the context of climate change adaptation. This guide explains how that can be done.

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