INCREASING THE RESILIENCE OF SMALL AND MEDIUM SCALE IRRIGATION SYSTEMS IN NEPAL

Simon Howarth[1], Sushil Tiwari[2], Prachanda Pradhan[3], Umesh Parajuli[4], Keshav Sharma[5]

ABSTRACT

Agriculture is a mainstay of the economy of Nepal, providing about 30% of the GDP and supporting livelihoods for the majority of the population. It is very vulnerable due to the monsoon climate as well as topography, and population growth has made land holdings too small to meet the subsistence needs of most people. Off-farm employment and rural-urban migration are increasingly important to supplement agricultural income. Irrigation is an important requirement for agriculture but, despite the long history of irrigation in the country, it is widely recognised that the sector is still in need of improvement, and that climate change will only make the situation worse.

This two-year study, funded by the UK Department for International Development (DFID) through the Climate Development and Knowledge Network (CDKN) draws on field studies of representative irrigation systems as well as analysis of climatic data and future projections to understand how farmers respond to an uncertain climate. Farmer perceptions and actions have been correlated with actual climatic data for the recent past, and related to future projections of climate change. Increases in peak flows are anticipated but, more importantly, small changes in timing, intensity and duration of rainfall coupled with increases in temperature have already influenced cropping particularly in winter. The ability of communities to adapt to climate and other changes depends on the strength of community-based organisations, the condition of infrastructure and the importance of agriculture in the local economy. Improvement of agricultural support services is needed to enable diversification into higher value crops, for which the growth of new markets resulting from rapid urbanisation and improved road access provides an opportunity. Catchment-level management is increasingly needed to manage water equitably, particularly as return flows from upstream systems form an important part of the inflow for downstream systems, and both technical and institutional improvements are needed at system level. Resilience needs to be addressed at individual farmer, community and irrigation organization levels.

Keywords: Irrigation, climate change, Nepal, farmer-management.

1. INTRODUCTION

Climate change is widely reported having a profound impact on Nepal and specifically on agriculture, which is highly dependent on the climate. Irrigation is a means for mitigating the impact, but it is in itself vulnerable to changes in climate – which may affect the magnitude of floods to be withstood or reduce the availability of water to be diverted. Much of the concern in Nepal relates to the impact of temperature rise on glacier retreat and on snow melt. Whilst these impacts are evident and widely reported, they are less significant for most irrigated agriculture which is more reliant

[1] Mott MacDonald Ltd., UK(Simon.howarth@mottmac.com)
[2] Deputy Director General, Department of Irrigation, Nepal
[3] Farmer Managed irrigation Systems Promotion Trust, Nepal
[4] Centre for Engineering Research and Development, Nepal
[5] ADAPT-Nepal

on smaller rain-fed rivers. The majority of irrigation (75%) is on small and medium scale irrigation which almost entirely relies on small rainfed rivers and groundwater and is already severely water-constrained.

It appears that the greater variability of the climate will have a negative impact on farmers who already have marginal livelihoods and push them further into poverty. This study aims to look at the impact on irrigated agriculture and to identify measures and policies to improve the resilience of irrigation.

Nepal has abundant water resources (225 km^3/year or 8,000m^3/person/year) in total but there is a marked temporal and spatial variation in their availability. Irrigation is the main consumptive use of water and 70% of the total potentially irrigable area of 1.8m ha receives some form of irrigation (Table 1). However, almost all of this is already water-deficient even before climate change has any impact.

Table 1: Irrigation in Nepal

Zone	Potential Irrigable Area	Irrigated Areas (ha)		
		Major & Large	Small & Medium	TOTAL
Tarai	1,337,581	317,233	677,764	994,997
Hills	368,541	5,540	176,774	182,314
Mountain	59,718		50,042	50,042
Sub-total	**1,765,840**	**322,773**	**904,580**	**1,227,353**
% total existing irrigated area		26%	74%	100%

Note small/medium denotes individual systems of less than 500ha in hills and 2,000ha in tarai

Most small/medium surface irrigation in the tarai is supplied from the small southern river basins which have just 13% of the total annual discharge and the nature of the rivers means that there are marked seasonal variations and thus a very inadequate water supply at critical times. Although irrigation in the hills is predominantly within the major river basins, most of this irrigation isin small rainfed sub-basins which have a low runoff and are water-stressed. Small and medium systems are almost entirely farmer-managed, although some support may be provided by the Government.The four major river basins (Kosi, Gandaki, Karnali and Mahakali) account for almost 78% of water resources and the five medium rivers (Kankai, Kamala, Bagmati, West Rapti, and Babai) a further 9%: these supply most of the large and major systems which are predominantly agency-managed, but with farmer involvement at lower levels.

Figure 1: River Basins in Nepal

2. METHODS

The structure of the study is illustrated in Figure 2. There are three main strands:

- Review of national policies, studies and reports
- Field studies – perceptions of change and responses
- Analysis of past climate data and future projections

These three strands will be synthesized to make recommendations for future development or improvement of irrigation. These are based on case studies, but generalised to the extent possible to the rest of the country.

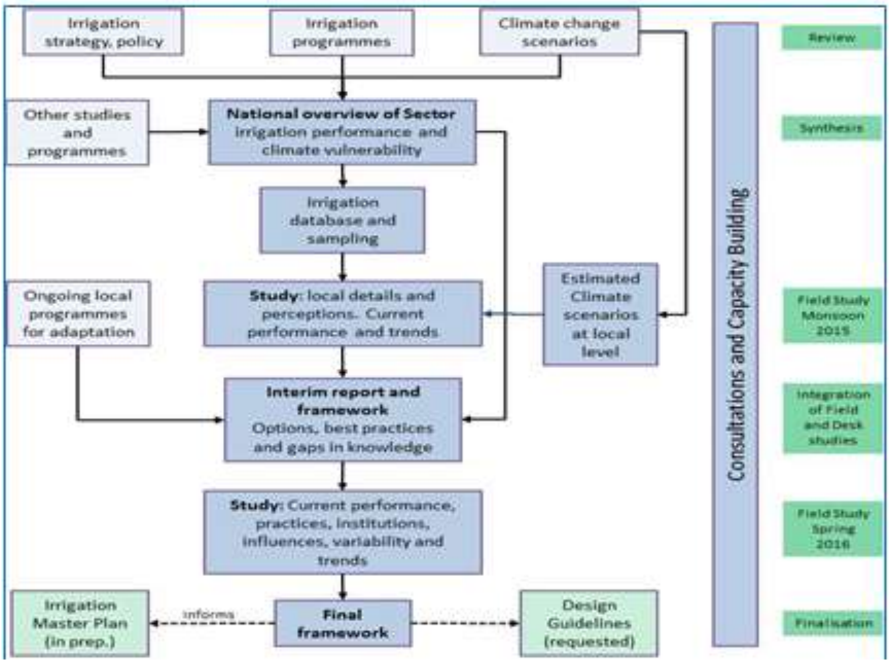

Figure 2: Structure of the Study

3. RESULTS AND DISCUSSION

3.1 Selection of case study areas

On the basis of a review of irrigation across the country, drawing on published database and local consultations in Kathmandu and bearing in mind the security situation and practicalities of rapid field visits, three areas were visited in September-December 2015 – central hills/mountains (Sindhuli and Nuwakot districts); western tarai (Nawalparasi, Rupandehi and Kapilvastu) and eastern Tarai (Jhapa) to cover a range of types of irrigation and situations. Further more detailed investigations are now being carried out in two river basins in the western tarai: Banganga in Kapilvastu and Girwari *khola* in Nawalparasi. There are several small/medium systems in each basin which are closely linked operationally and hydrologically.

3.2 Past Trends in Climate

Long term records on climate are sparse and there are concerns over the accuracy of some stations. The station at Bhairahawa(in Rupandehi District) has relatively long records and is believed to be reliable. This is close to the study sites and gives a good indication of past climate trends in the area. This data can be supplemented by shorter term records for sites closer to the individual sites to assess microclimatic variations, due to topography.Temperature trends are well-defined, with small but significant rising trends. More rapid trends can be seen in other locations in Nepal – particularly the mountains - but there is less change in the tarai where most of the irrigation is located.

Figure 3. Location of Study Sites

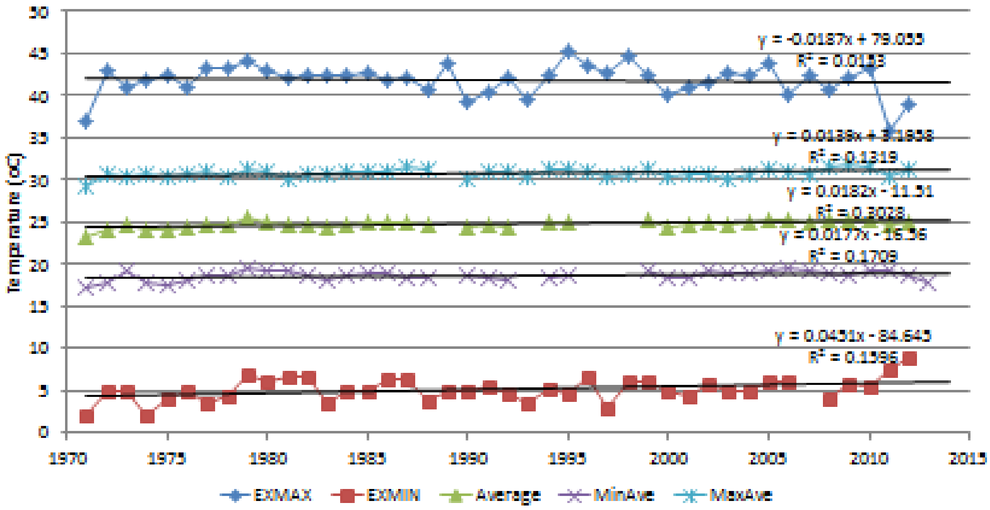

Figure 4. Temperature Trends in Bhairahawa

Rainfall does not show such clear trends as this is a highly variable parameter, subject to large natural variations between years which are much greater than observable trends so far. Although there may appear to be emerging trends in rainfall, these are for the most part not significant. Over the past 40 years, annual rainfall has fluctuated between 1,000 and 2,000mm with occasional more extreme years. Almost all falls in the monsoon (Juneto September). The slight downward trend indicated by a linear regression is very small compared to the annual variability.

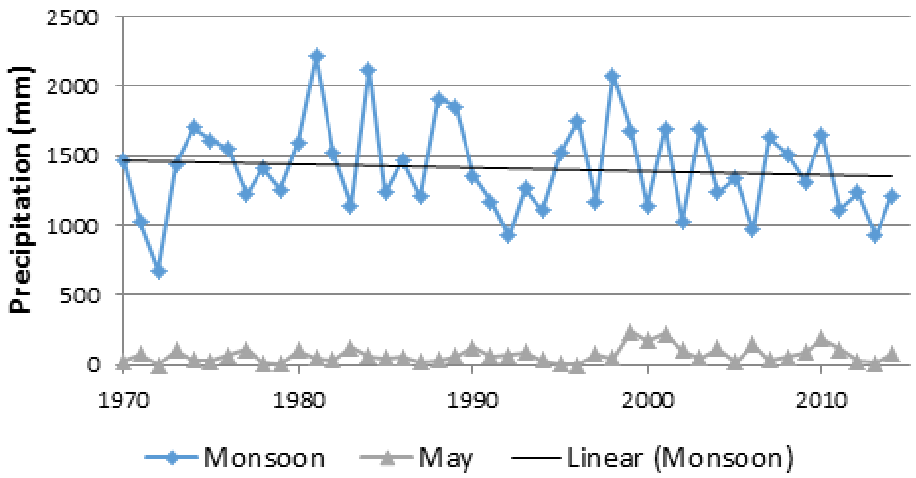

Figure 5. Monsoon Rainfall Trends in Bhairahawa

Despite this, farmers commonly report adverse trends in rainfall. Whilst this may partly be a generic, non-specific complaint it does appear that there have been some more subtle but significant changes in the timing, intensity and frequency of rainfall. There have also been stronger apparent changes in recent years, which are likely to influence farmer perceptions. For example rainfall decreased from 1,900 to 1,300mm between 2010 and 2013. Rainfall in May is important for a timely start to the monsoon crop, and there is some indication of an increase in this, but any benefit may be offset by a slightly greater variability.

The monsoon starts on average on 10 June in East Nepal, reaching the west of the country five days later. This has changed little, despite a variation of plus or minus 10 days. However, there has been a significant trend towards a later end date in September. This means that the monsoon rainfall is spread over a longer period and is possibly more intense but more intermittent. An increase inthe frequency and duration of dry periods and increase in intensity of rainfall events would increase both the flood risk during storms and crop damage during the longer dry periods. It would also make it more difficult to diversify to non-rice crops, which is essential for profitable agriculture. However, available data does not suggest this is happening yet.

The dry season rainfall is much less than the monsoon but is essential to ensure the dry season river flows needed for irrigation at that time, as there is limited scope for water storage. The variability of rainfall is also much greater, with some years having no rain for six months but others with up to 250mm. The rainfall in the period January to April is most critical for perennial agriculture – this appears to be increasing slightly, but there is a very large annual variation making agriculture very unpredictable, and there may be also be more subtle variations in the timing and magnitude of rainfall events. Although irrigation is intended to mitigate the impact of variations in rainfall, the availability of water in the small rivers used for most irrigation is closely correlated with rainfall. This means that irrigation is most unreliable when it is most needed.

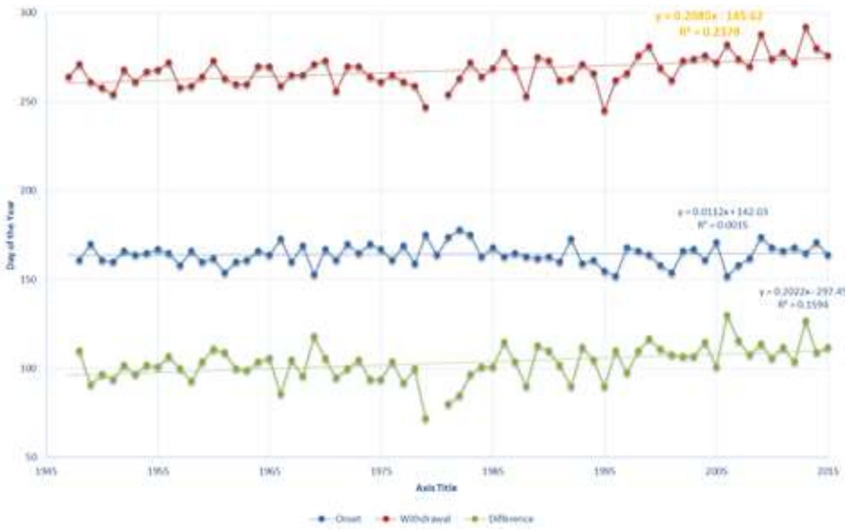

Figure 6. Monsoon Timing and DurationTrends in Bhairahawa

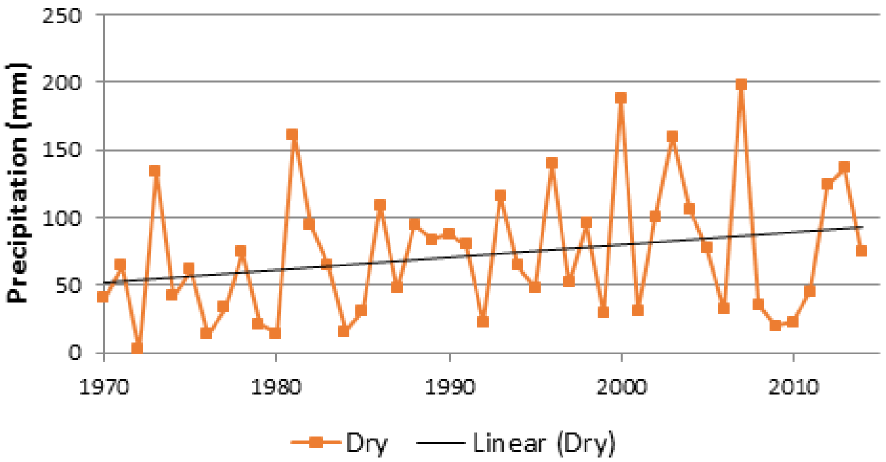

Figure 7. Dry Season Rainfall Trends in Bhairahawa

These changes in temperature and precipitationto date are unlikely in themselves to be sufficient to force a change in cropping or in livelihoods but they will reinforce other trends which are driven by other factors – a reliance on off-farm incomes, a reluctance to diversify, population growth and land fragmentation. However, future projections suggest that more profound changes can be expected.

Future Projections of Climate

As the current situation is so variable, it is to be expected that there will be a much greater uncertainty in the future climate. The CMIP5 project (Coupled Model Intercomparison Project Phase 5) draws on 20 modelling groups to demonstrate the range of future rainfall patterns. Diagrams showing national trends in Nepal are shown below for two three-month periods: June-August to represent the monsoon; and March to May to represent the dry season. These periods are slightly different from those used in the earlier analysis, but this does not affect the conclusions.

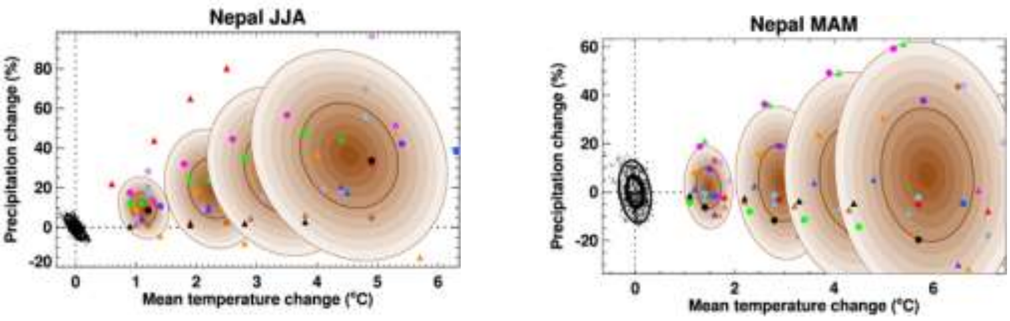

Figure 8 Future Precipitation Projections for Nepal

The change in temperature (x-axis) is the difference between the future climate and the 1961-1990 mean. The national average precipitation (y-axis) is expressed as a percentage change from the 1961-1990 mean. The global warmings of 1, 2, 3 and 4°C at any particular time vary according to the emission scenario and model. The spread in the projections from these multi-model ensembles is visualized by the shaded ellipses. The outer ellipse line marks the +/-2 standard deviation range of the models in each ensemble, while the inner ellipse line marks the +/-1 standard deviation range.

Under the current situation (0^o temperature change) the monsoon rainfall is quite uniform (±10%), but with a 4^{o}C rise in temperature the change in monsoon rainfall will increase to -20% to +80%. Thus there is a potential large change with not even consensus on the direction of change. The situation in the dry season is even more severe. The current variability is rather greater (±15%), but this will increase to ±60% - with great uncertainty in both direction and magnitude of change. Possibly even more significant is the fact that these figures represent 3-monthly totals, and within these there may be greater changes in rainfall intensity or in dry periods influencing both flood flows and droughts. Designing for the worst case, or even a situation with 80% confidence in 25 years' time which is a common design basis for irrigation, is likely to be impossible or uneconomic. But ignoring climate change risks that schemes may fail rapidly due to flood damage, or they may simply perform much less well than envisaged and may not warrant the effort needed to keep them in operation

Farmer Perceptions

These trends can be corroborated by farmer perceptions. Warmer winters are reported to mean that the climate is increasingly suited to mustard and potato rather than wheat although this may partly be driven by economic factors. More erratic rainfall can also be seen, and means that irrigation is increasingly important even during the monsoon longer dry periods in the late monsoon are reported to affect productivity, although paddy area is reported to be unchanged. Informal observations, such as potato flowering dates or peach blossoming, also confirm that temperature is rising.

Groundwater irrigation can easily be delivered when required but requires expensive pumping, whereas surface irrigation is more difficult to manage but costs much less. Good irrigation systems are protective against climate change, and improving management will make irrigation more resilient as well as perform better under present climate.

Very few if any small catchments are reliably monitored for runoff but there are believed to be significant changes in recent years. Flood flows are believed to have increased, and these perceptions can be corroborated by observations of peak flood levels. Dry season runoff appears to have declined, but this is less easy to confirm and is also more directly influenced by other factors such as changes in land use in the catchment, population growth, increased abstractions further upstream, and more efficient (impermeable) weirs for upstream systems. However, there are strong perceptions of increased flood flows as well as declining dry season flows.

3.5 Climate Change in Context

Agriculture and livelihoods in Nepal have changed fundamentally in recent decades for many reasons. There has been rapid population growth, leading to fragmentation of land holdings which are insufficient for basic subsistence-level agriculture. This has made off-farm employment essential for livelihoods, and much of this has depended on seasonal or long-term migration to urban areas in the tarai or Kathmandu, or internationally. Between 2001 and 2009 remittance income increased by over 20% per year and was 22% of GNP in 2009, whereas crop area in western tarai remained almost unchanged and total agricultural production grew by just 3.5% - slightly ahead of population growth (1.8%).

Paddy remains the dominant crop in the case study districts, at 60% of the crop area with wheat covering a further 24% and oilseeds 6%. Yields remain low by regional standards (paddy 3.7 tonne/ha, wheat 3.0 tonne/ha in 2010 in the study districts), but have risen by 40-50% over the past decade – particularly wheat and maize. Thus, despite slight improvements, agriculture remains below subsistence level with livelihoods dependent on off-farm employment and remittances. Paddy remains important for local food security and can be grown quite easily without needing intensive continuous activity, unlike high value cash crops such as vegetables. Paddy can be grown more readily without detracting from off-farm work, whereas vegetables require a continuous local presence. This makes it difficult for many households to diversify even if water management can be improved.

The high variability in the historic climate with no significant trends, coupled with much larger trends in other critical factors such as population and off-farm employment suggests that climate change is not yet having a significant effect on irrigation in most cases. However, there are some indications of important changes in rainfall patterns – such as extended dry periods in the late monsoon in 2014 and 2015. Projections for future climate clearly indicate a risk that there will be a greater impact in due course.

More immediately, it is the poorest farmers who have the highest dependence on agriculture and the fewest alternatives, and thus are most affected by the additional challenges posed by climate. The distribution of impacts is being investigated in more detail now, but it appears that the poorest are already suffering from this. There is also some evidence that floods are increasing – the 2014 flood in the Babai river greatly exceeded the design flood (about 50% more than 1 in 100 year flood), and the 2015 flood in the Biring river was the highest in living memory. These floods may be partly due to upstream land use changes, but clearly suggest that climate change poses a significant threat.

3.6 Implications for Irrigation Design and Management

Most small and medium irrigation is long-established, and even new systems are designed in largely traditional ways despite some innovations such as permanent weirs, greater use of canal lining, and provision of formal control structures. These innovations can, however, create additional risks if they are not well designed – particularly in relation to flood flows. Traditional systems relied on leaky boulder and brushwood weirs to divert water into earthen canals which had few formal structures although arrangements for proportional division of flows within canals are common. Maintenance requirements are high as the weirs may get damaged even in a normal monsoon and minor breaches or blockages in canals due to landslides are frequent. However, these only need labour and local materials to repair them.

New or upgraded systems often have concrete weirs which enable diversion of the entire river flow and are resilient against monsoon damage but are more difficult to repair if there is a more extreme flood than designed for. Traditional weirs leave much of the water in the river for downstream systems, whereas modern weirs are impermeable and expensive so they may be used to provide water for several traditional systems via a link canal. This has implications for management, as it changes traditional arrangements, but is efficient if well-managed.

Traditional systems are vulnerable to damage, but they can be resilient as well: damage is usually small-scale and easy to repair with local skills. However, they do require strong management as well as ample labour: both of these are threatened by the trend to off-farm employment and emigration. Where there is still a strong demand for irrigation, management has responded through better arrangements for raising cash and employing external maintenance workers. Modern systems should be easier and cheaper to maintain but they can be more vulnerable (an expensive) if conditions exceed the design parameters – for example, if floods damage or bypass permanent weirs. Flood flow estimation procedures need to be improved, or arrangements for fail-safe design through fuse plugs or other techniques are needed.

Irrigation aims to augment unreliable or inadequate supplies from low rainfall, but as it is already marginal – there is almost invariably less water than required for the entire command area – any change in rainfall pattern or temperature can have a disproportionate impact on water requirements. Most irrigation is supplementary to rainfall and thus an extended period without rain – as appears to be increasingly common in the late monsoon period – will increase the need for irrigation, and increases in temperature will increase the crop water requirements.

4. CONCLUSION

Climate in Nepal is changing, and any changes are likely to have an impact on irrigation. Small and medium irrigation is dependent on rainfall, and changes in frequency, duration and intensity will affect irrigation requirements as well as design and management arrangements. The changes are so far small, but they compound the impact of other changes such as population growth, urbanisation and other land use changes, livelihood diversification, migration and security. These observations are primarily based on observations and data from the western tarai; they should be generally applicable in other parts of the country, although slightly greater change in climate is reported from hills.

Measures to improve the resilience of irrigation in face of climate change will also improve the resilience in other respects, and help farmers take advantage of many new opportunities. These opportunities include new varieties (higher yield, better drought resistance, more appropriate maturity time, etc); higher demand for high value crops (fruits, vegetables and spices); better access to markets; and increasing availability of affordable and reliable groundwater irrigation.

These findings suggest that some changes to the procedures for supporting and managing small and medium irrigation would be beneficial. The increasing pressure on resources has created a demand for more ‘efficient’ irrigation, in terms of reducing local losses. However, lining canals and construction of permanent weirs reduces the return flows which are an important source of water for downstream users. Thus there is a growing need for better institutional arrangements for managementat a river basin level, and options for combining systems through provision of link canals should be explored. These reduce the number of diversion works in the river which are vulnerable to flood damage, but equally they increase the impact if any damage does occur in the river. Thus they should only be provided if there is an improved process for peak flow estimation, with fail-safe arrangements so that the damage caused by more extreme events is confined to fuse plugs or other such arrangements rather than causing extensive damage.

Most irrigation is in small rivers which rise and fall very rapidly – making abstraction difficult in dry seasons (often requiring temporary canals through dry gravel river beds), whilst causing flood damage in the monsoon. There needs to be a risk-based approach to design for such diversions and intakes, with better arrangements for flood and sediment control at permanent intakes.

Low flows are decreasing for a variety of reasons, but procedures for estimation of low flows in these ungauged catchments are out of date and inaccurate. Management of these increasingly variable but declining flows necessitates consideration of individual schemes as part of integrated systems at catchment level, so that water use can be optimised across the catchment

Crop water requirements and delivery mechanisms for winter and spring cropping also need to be updated to suit the current and future potentially more diversified cropping. Groundwaterirrigation has emerged in recent decades as a major development for diversified crops in tarai and suitable river valleys in the inner tarai and hills, but needs support to make it financially feasible and sustainable – particularly for poorer farmers.

Climate change poses a challenge for irrigation in Nepal but also an opportunity as it can be driver for changes that would be needed even under present climatic conditions. There are many other changes affecting irrigation, agriculture and rural livelihoods and it is essential that responses to climate change are planned in this context.