

# Water, Climatic Variability and Livelihood Resilience: Concepts, Field Insights and Policy Implications

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## Contents

|  |           |
|--|-----------|
| <b>FOREWORD</b> .....  | <b>2</b>  |
| <b>CORE ARGUMENTS</b> .....  | <b>3</b>  |
| <b>INTRODUCTION</b> .....  | <b>5</b>  |
| <b>CONCEPTS OF ADAPTATION AND RESILIENCE</b> .....   | <b>7</b>  |
| DEFINITIONS .....  | 8         |
| SYSTEM DYNAMICS .....  | 12        |
| THE CASE OF GROUNDWATER IN SOUTH ASIA: AN EXAMPLE .....                                    | 14        |
| <b>INSIGHTS FROM THE FIELD</b> .....   | <b>16</b> |
| ADAPTATION TO DROUGHT IN GUJARAT & RAJASTHAN .....   | 17        |
| ADAPTATION TO FLOODS IN EASTERN UTTAR PRADESH, BIHAR AND THE NEPAL TERAI.....              | 20        |
| ADAPTATION TO LONG-TERM WATER SCARCITY IN YEMEN .....                                      | 25        |
| SUMMARY OF INSIGHTS FROM THE FIELD.....  | 30        |
| CONTRASTS WITH CONVENTIONAL STRATEGIES: ADAPTATION VS INTEGRATED WATER RESOURCE MANAGEMENT | 31        |
| <b>FROM OBSERVATIONS AND CONCEPTS TO POLICY</b> .....                                      | <b>34</b> |
| CONCEPTUAL FRAMEWORKS AND OBSERVED BEHAVIOR.....   | 34        |
| POLICY IMPLICATIONS .....  | 35        |
| <i>Trans-boundary Policy Arenas</i> .....  | 35        |
| Migration & Commuting.....   | 36        |
| Remittances & International finance flows.....   | 37        |
| Information Flow: Communications and Advanced Warning Systems .....                        | 37        |
| <i>National and Local Policy Issues</i> .....  | 39        |
| The establishment of community-based institutions.....                                     | 39        |
| Approaches to water management. ....   | 39        |
| Credit and Banking Systems.....  | 41        |
| Rural Economic Development Policies .....  | 41        |
| <i>Programmatic - Disaster Mitigation and Development Programs</i> .....                   | 41        |
| <b>CONCLUSIONS</b> .....   | <b>43</b> |
| <b>BIBLIOGRAPHY</b> .....  | <b>45</b> |

## FOREWORD

This is the second policy report from the Resilience and Freshwater Initiative (RFI). The ambition of the initiative is to make emerging scientific theories of resilience operational for policy making that concerns integrated water management. The initiative includes a wide scope of network partners such as Stockholm University, Institute for Social and Environmental Transition (ISET), Stockholm Environmental Institute (SEI) and Stockholm International Water Institute (SIWI). The findings from this report are however, the sole responsibility of the author.

As will be discussed and elaborated in this report, the perspective offered by emerging theories of resilience adds some important and previously poorly elaborated dimensions to what is usually denoted Integrated Water Resource Management (IWRM). Put bluntly, while IWRM suggests an approach that “promotes the co-ordinated development and management of water [...] in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP 2000:22), a resilience perspective complements this view with an approach that promotes social learning, experimentation and attempts to enhance the ability of actors to tackle uncertainty, complexity and environmental change.

The following report highlights the fundamental importance of understanding adaptive processes and the factors contributing to livelihood resilience if the



world is to meet the Millennium Development Goals. The report also highlights the central role water plays in current rural livelihoods in developing countries, and the impact existing climatic variability and anticipated climate change will have on those livelihoods. In addition, the report discusses how policy-initiatives might produce outcomes that sometimes reduce the resilience of social-ecological freshwater systems, hence contributing to vulnerability. The results should therefore be of interest to all those concerned with how to secure the bloodstream of both nature and society: water.

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## CORE ARGUMENTS

Adaptive capacity and the ability to build resilient livelihoods are, perhaps the two most fundamental challenges facing global society in a context where variability and rapid processes of change dominate the world in which we live. Sustainability has, in fact, been defined as the ability to “create, test and maintain adaptive capacity” (Gunderson and Holling 2002) p.76. This ability to adapt will be of increasing importance over coming decades as climatic change coupled with dynamic changes in economic and demographic systems reshapes livelihoods at rates and scales that are probably unprecedented in human history.

Research in South Asia and other parts of the world provides preliminary insights into the critical roles diversification, human mobility (migration and commuting), transportation, financial and communication systems, resilient ‘adaptive’ infrastructure, institutional systems, secure water supplies and natural resource conditions play in livelihood resilience and adaptive capacity at the household and regional level in drought and flood affected areas (Hussein and Nelson 1998; Moench and Dixit 2004; Wisner, Blaikie et al. 2004; Brown 2005). Across much of the developing world, agriculture serves as the fundamental livelihood basis for most of the world’s poor. Agriculture is, in turn, dependent on access to reliable water supplies whether directly from rainfall or through irrigation systems. If climatic variability and extreme events increase as a consequence of climatic change, already vulnerable agricultural livelihoods will be increasingly under threat. The ability to move out of poverty - and in many cases the ability to survive - will depend on their capacity to increase the resilience of existing agricultural livelihoods and, in many cases, diversify and move into new non-agricultural livelihood systems. The resilience of agricultural systems will, in turn, depend heavily on strategic approaches to water management capable of addressing constraints as they arise at local and community levels (Moench 1999; Moench, Dixit et al. 2003).

The above insights, while founded on substantial research, are at best preliminary. While pointing toward broad factors, they provide limited tangible guidance regarding specific courses of action that can be taken in local areas. The Millennium Development Goals set challenging targets for poverty alleviation and development. If they are to be met, improved understanding adaptive processes and the factors contributing to livelihood resilience will be essential. This said, existing insights on the factors contributing to adaptive capacity and livelihood resilience already have fundamental implications for approaches to development, disaster relief and international relations. Many of these implications point toward the need to strengthen and retarget basic development processes particularly those related to water management, agriculture and non-farm livelihoods at local levels in order to create the social capital and other foundations on which resilient adaptive livelihoods must rest.

Disaster relief will be another critical area. Floods, droughts, extreme storms and other disasters disrupt livelihood systems. While relief is essential, disruption often presents an opportunity for diversification and other changes that increase resilience and adaptive capacity. Rather than rebuilding existing patterns of vulnerability, it is increasingly essential to restructure disaster responses away from palliative measures and develop approaches that respond to underlying structural problems within livelihood systems as well as immediate needs. To put it another way, practical mechanisms need to be developed and implemented that integrate disaster relief, disaster risk reduction and development. Finally, existing insights on adaptation raise issues that have significant implications for international relations at a global level.

Adaptive capacity depends heavily on mobility and access to systems that enable people, information and goods to flow freely into and out from affected areas. It also depends on the ability of local populations to create and accumulate financial and other capital - the resources required to evolve new livelihoods or strengthen existing ones. Migration is a central and often proactive strategy required to obtain access to global labor markets. If human induced climate change undermines the viability of local livelihood systems, affected populations may demand the right to migrate and obtain access to jobs and other livelihood support systems in regions that have benefited from activities implicated in climate change. Similarly, with agriculture as the livelihood basis for most of the world's poor, global agricultural trade and regional subsidy policies have fundamental implications for the ability of local populations to accumulate the financial and other resources necessary to develop adaptive resilient livelihood systems. With increasing finger pointing over the drivers of climatic change, debates over subsidy systems, protectionist policies and demands for preferential treatment within the global agricultural trade system could, as a result, intensify substantially.

The purpose of this paper is to summarize some of the preliminary results emerging from existing theoretical and applied research on adaptation and livelihood resilience and explore implications for policies related to disaster relief and development. Because most of the world's population, particularly the poor, depend on agriculture for their livelihoods, it focuses heavily on agriculture and the role climate and related water issues play in relation to it. Agriculture is, however, declining as the foundation of many livelihood systems as economic, transport and communication systems increase the density of links between rural and urban areas. "Peri-urbanization," the growth of truly urban populations and the accompanying increase in rural non-farm economic activities are all part of a global transition that is reshaping the role agriculture plays in livelihood systems. As a result, the paper explores elements of the ongoing transition in economic systems and the implications of this transition for responses to climatic variability and change. In addition, the paper highlights issues related to global policies on migration, trade, and finance that

have yet to emerge in global debates on climate change but appear likely to be based on emerging research insights.

The paper is organized in the following manner: The introduction highlights recent insights from global research on climatic change and the emerging debate over adaptation. This background is used to emphasize the critical role adaptive capacity and the development of resilient livelihoods will play over coming decades. Resilience and adaptive capacity, while perhaps intuitively clear, are far from simple concepts. As a result, the following section explores conceptual and theoretical insights from the emerging science on dynamics and processes within interlinked socio-ecological systems. This theoretical perspective is then grounded in practical examples drawn from India, Nepal and Yemen along with a comparison to Integrated Water Management Approaches. The final sections focus on implications for water resource management, regional development, disaster relief and other critical global policy arenas.

## INTRODUCTION

The Millennium Development Goals set three challenging water related targets: Halving world hunger, halving the number of people in poverty and halving the proportion of the world's population without access to sustainable sources of safe drinking water and basic sanitation. Meeting the first two of these goals depends on agriculture and the reliability of agricultural water supplies. Globally, much of the population, particularly in developing countries, depends on agricultural livelihoods. In some regions, such as South Asia, over 70% of the population is rural. Their current income and ability to accumulate the capital required to move out of poverty - and often into non-agricultural livelihoods - is heavily influenced by the nature of water supplies for irrigation and domestic uses (Moench 2003). Beyond anything else, reliability is the central requirement. Droughts and even relatively minor fluctuations in water availability often dramatically reduce agricultural yields (Herdt and Wickham 1978; Meinzen-Dick 1996; Meinzen-Dick 1997; Perry and Narayanamurthy 1998). Even if water is adequate during all the rest of the crop season stress at the flowering stage of maize, the staple food crop across much of Africa, can reduce yields by 60% (Seckler and Amarasinghe 1999). Similar impacts are known for many other crops. As a result, fluctuations in water availability are often the catalyst for losses that consume accumulated capital and destroy investments made in seeds, fertilizer and other agricultural inputs. Furthermore, the impact of variability often goes far beyond crop yields. When droughts are severe they drain labor availability and increase social inequity as individuals, most frequently women, are forced to walk long distances or spend valuable time waiting in line to obtain basic supplies of, often low quality, water for domestic use. This, in turn, has major impacts on health and education; that is to say the foundations for poverty alleviation and any productive livelihood.

At a global level, society's ability to meet the millennium development goals is complicated in fundamental ways by the increases in climatic variability now occurring and increasingly anticipated as a consequence of global climatic change. The IPCC Third Assessment Report (IPCC 2001) highlights existing and probable changes in water related systems that include:

1. Increases in heavy precipitation events;
2. Increases in the frequency and severity of drought;
3. Increases in the number of hot days;
4. Increases in the frequency of El Nino events
5. Exacerbation of water shortages in many water-scarce areas of the world; and
6. Increases in climatic variability including changes in frequency, intensity and duration of extreme events such as hot days, heat waves, heavy precipitation events and fewer cold days.

The above changes have the potential to reduce the reliability of water supplies for rural communities while also increasing the importance of access to such supplies in order to buffer both higher demands for water associated with increased temperatures and the need for reliability to meet plant and domestic water supply needs as climatic variability increases. One direct consequence identified by the IPCC is a probable decrease in the yield of cereal crops in most subtropical and tropical areas (IPCC 2001). The likely impacts, however, extend well beyond this because of the core role water supply reliability plays in the ability of rural agricultural populations to accumulate and maintain assets. The expansion of groundwater irrigation has, for example, played a central role in poverty reduction across South Asia in large part because of the reliable nature of groundwater resources as a source of irrigation water (Moench 2003). In other areas, such as the Central Valley of California and the Negev desert, the value of groundwater is far higher than water from surface sources primarily because of its reliability (Tsur 1990; Tsur 1993). Groundwater resources are now over developed and water levels are declining in many parts of South Asia, China, the Middle East, the western U.S. and Mexico (World Bank and Ministry of Water Resources - Government of India 1998; Seckler, Barker et al. 1999; Wester, Pimentel et al. 1999; Burke and Moench 2000; Shah, Molden et al. 2000; Khater 2003; Roy and Shah 2003; Shah, Roy et al. 2003; Wang, Zhang et al. 2005). As a result, declines in the availability and reliability of key buffering water sources, such as groundwater, will compound the impacts of climatic change. Effective management strategies capable of increasing the reliability of water supplies to individual end-users will be essential. Furthermore, such strategies must respond not just to climatic variability and change but also to other processes - such as groundwater overdraft - that undermine the condition of the water resource base.

The case of agricultural populations represents one clear example of the probable consequences of global climatic change. Such consequences are, however, not limited to agricultural populations alone. The vulnerability of populations residing in coastal areas where sea level rise combined with increases in extreme events is well known. Possibly more importantly the IPCC identified a potential increase in the risk of abrupt and non-linear changes in many ecosystems, which would affect their function, biodiversity and productivity (IPCC 2001). This could have a major impact on any population where local livelihoods depend directly on fisheries, animal husbandry or any similar natural resource system.

Global efforts to control greenhouse gas emissions are now widely recognized as insufficient to control anticipated climatic changes. This was clearly evidenced by the central role discussions over adaptation played at the COP 10 negotiations on climate change in Buenos Aires, December 2004 and at the World Conference on Disaster Relief in Kobe, January 2005. Even under the most optimistic scenarios prepared by the IPCC, significant temperature changes are expected to occur before the end of this century. According to summaries of model results produced by Working Group I of the IPCC, “For the end of the 21st century (2071 to 2100), the mean change in global average surface air temperature, relative to the period 1961 to 1990, is 3.0°C.”<sup>1</sup> Adaptation and efforts to increase the resilience of livelihood systems will, as a result, be essential.

## CONCEPTS OF ADAPTATION AND RESILIENCE

What do the terms ‘resilience’ and ‘adaptive capacity’ mean? On a simplistic level, resilience is the ability of a system to maintain its structure and function when subject to disruptive forces and adaptive capacity is the ability to successfully accommodate the impacts of change. In the climate change context, UNDP and the Global Environmental Facility define adaptation and adaptive capacity respectively as “a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed and implemented” and “the property of a system to adjust its characteristics or behaviour, in order to expand its coping range under existing climate variability, or future climate conditions” (Lim and Spanger-Siegfried 2004) These definitions do not, however, provide much guidance regarding the nature of resilience, adaptation and adaptive capacity in complex changing social and environmental contexts. Since this guidance is central to the identification of strategies capable of responding to climatic change, understanding the conceptual foundations of these terms and their relationship to processes observed ‘on the ground’ is essential. I’ll start this by briefly exploring the conceptual foundations of adaptation and resilience and

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<sup>1</sup> [http://www.grida.no/climate/ipcc\\_tar/wg1/031.htm](http://www.grida.no/climate/ipcc_tar/wg1/031.htm) accessed on May 30, 2005

relating these to the observed behavior of interlinked social-ecological systems.

## DEFINITIONS

As defined by the Resilience Alliance, ecosystem resilience is:

“the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future. Humans are part of the natural world. We depend on ecological systems for our survival and we continuously impact the ecosystems in which we live from the local to global scale. Resilience is a property of these linked social-ecological systems (SES). “Resilience” as applied to ecosystems, or to integrated systems of people and the natural environment, has three defining characteristics:

1. The amount of change the system can undergo and still retain the same controls on function and structure
2. The degree to which the system is capable of self-organization
3. The ability to build and increase the capacity for learning and adaptation”<sup>2</sup>

Clarifying this a bit further, Walker and Holling *et. al*, define resilience as “the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks.”(Walker, Holling et al. 2004). Adaptability is closely related to this....in their definition it is “the capacity of actors in a system to influence resilience” and they argue that this is, in effect, an outcome of “individuals and groups acting to manage the system.” The third key element they define is transformability...“The capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable.” (Walker, Holling et al. 2004). Elsewhere adaptive capacity has been defined as “the ability of socio-ecological system to cope with novel situations without losing options for the future” (Folke, Carpenter et al. 2002).

<sup>2</sup> ([http://resalliance.org/ev\\_en.php?ID=1004\\_201&ID2=DO\\_TOPIC](http://resalliance.org/ev_en.php?ID=1004_201&ID2=DO_TOPIC)) Resilience Project web site accessed 1/28/04.

These definitions serve as a useful starting point. It is, however, important to recognize their limitations in relation to the complex concepts they are attempting to summarize. As the authors note, “An inherent difficulty in the application of these concepts is that, by their nature, they are rather imprecise.”(Walker, Holling et al. 2004). More importantly, existing definitions do not fully capture the continuous nature of most systemic change processes. Climate and other systems can undergo continuous processes of change that ultimately change their structure. Human induced changes are an added element that may change the direction, speed and magnitude of existing climate change processes - but change *per se* is nothing new. While climate systems may, from a human perspective, appear essentially stationary (and assumptions of stationarity underpin disciplines such as hydrology) as the ‘ice ages’ evident in the geologic record demonstrate, conditions often change in fundamental ways over long periods of time. As a result, what constitutes a fundamental change in system characteristics is often a matter of perspective and time. A rural agricultural economic system may, for example, be able to absorb the disturbance associated with a brief drought - while gradually undergoing fundamental structural transformations as transportation, communication, and wider economic changes alter the context in which that system exists. This is, in fact, the history of agricultural transition in many rural areas throughout the world. On a year-to-year basis, rural livelihood systems are often highly resilient - that is people are able to absorb the impact of droughts, floods, economic fluctuations, pest attacks and so on while the agricultural-economic system retains its core structural features. Over longer time horizons, however, such systems reshape themselves in fundamental structural ways even in the absence of any distinct period when they may appear untenable. In the 1800s most of the population in the U.S. depended on agriculture for their livelihoods, now less than 3% of the population does. In Spain the share of the labor force in agriculture has declined from approximately 50% of the total population to 6% within the last two generations (Garrido, Martinez-Santos et al. 2005). While sudden shocks (such as the ‘dustbowl’ of the 1930s in the U.S. and the growth of the EU in Europe) have occurred, the overall process has been a gradual but fundamental restructuring of the agricultural-economic and associated livelihood system over more than a century.

The above example points toward two other features central to resilience and adaptation: the pace and direction of change. Societies are particularly sensitive to the speed of system change and impacts of change on the ability of a system to produce the goods, services and other resources on which livelihoods depend. Declines in productivity within environmental, economic, or livelihood systems often translate into lower standards of living and the reverse is also true. The direction of change in system productivity is, as a result, important. The pace of change is equally relevant. When a shock is sudden and unanticipated, less time is available for systems to adjust or people to adapt. While small shocks (frequent droughts, etc...) can provide the

incentive for longer-term structural changes, larger shocks often disrupt the flows of resources on which livelihood and environmental systems depend. Declines in productivity often result, at least over the short term. Equally importantly, however, sudden change often has huge consequences on the distribution of resources within a system as niche activities are eliminated. In economic terms this often translates into high unemployment rates within affected sectors. In environmental terms it may be the extinction of species. Sudden fundamental change in systems tend to have much more serious consequences for the people and species than changes which occur gradually and allow time for adaptation occur.

For the above reasons, definitions of resilience and adaptability need to take into account both rates and directions of change in relation to system productivity and resource distribution.

A resilient SES is one that can absorb the impact of sudden shocks (possibly while undergoing processes of fundamental transformative change) without large losses in overall productivity or changes in the distribution of resources and access to resources by individuals within the system. This means, for example, that in practical terms an agricultural ecosystem system is resilient if it can absorb the impact of droughts, economic fluctuations, wars and other disruptions without causing major declines in production, increases in poverty or the loss of key environmental values. Similarly, a water management system is resilient if it can continue to provide key services (water for domestic uses, irrigation, environmental values, etc...) and avoid disruptive dynamics (floods, quality declines, etc...) when subject to natural variability, extreme events and climatic change processes.

Adaptive capacity is the ability of entities (individuals, groups, institutions, species, etc.) within a SES to respond to both sudden and long-term changes that fundamentally alter system characteristics without facing large declines in the overall productivity of the system or causing distributional changes that undermine access to resources or the quality of life for the individuals involved. This is similar to the definition used by Folke *et al* when they state that 'systems with high adaptive capacity are able to re-configure themselves without significant declines in crucial functions in relation to primary productivity, hydrological cycles, social relations and economic prosperity (Folke, Carpenter et al. 2002). To put it another way, regions with high levels of adaptive capacity are able to adjust to fundamental shifts in system characteristics without major increases in poverty, species extinction, environmental degradation and so on. In practical terms related to climate this would mean that regions would be defined as having a high level of adaptive capacity if progress on key social and environmental objectives (economic growth, poverty alleviation, the protection of ecosystems) continues to be made despite climatic changes that, for example, undermine the resilience of and led to failure in some individual sub-systems. Furthermore,

this adaptive capacity could be evident either in the region's ability to improve water management systems so that they were resilient in the face of change...or if the social objectives continued to be achieved despite fundamental changes (failures) in the ability to maintain water management systems in the face of climate change.

The above descriptions, while probably no more precise than those put forth by the resilience alliance and UNDP-GEF, are distinct in several important ways:

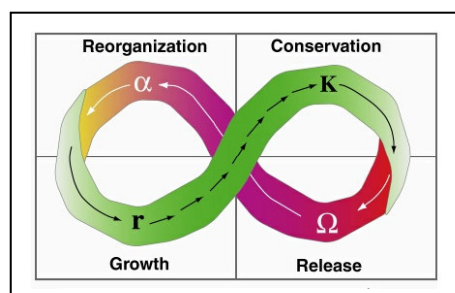
1. They define resilience, adaptability and adaptive capacity in relation to the ability to adjust or compensate to on-going transformative change processes rather than in relation to maintaining the resilience of specific sub-systems - in other words, adaptation isn't just about improving management or the ability of management approaches to maintain existing systems (although those activities are part of adaptation) it's about the ability to adjust and compensate effectively when fundamental changes are taking place.
2. Unlike the UNDP-GEF focus where adaptation is defined in relation to conscious strategies that are 'developed and implemented' (Lim and Spanger-Siegfried 2004), the descriptions here are as much about the ability of systems to adjust and change whether or not that adjustment comes about as a result of conscious strategic decisions or as an emergent property of the system itself. Markets, for example, have a high degree of capacity to change their structure in response to prices and other economic factors....but such adaptation is an emergent property of the system rather than the result of some group developing and implementing a strategy.
3. They focus heavily on the productivity and distribution of human and environmental services rather than the specific nature or structure of the underlying system producing these services. Most people 'care' about the quality of life, income levels, the maintenance of environmental values and similar objectives. They don't 'care' as much about the specific structural features of the underlying system producing those goods. To put it another way, most people care about whether or not water flows out of their tap, they often don't ultimately care if it comes from groundwater, a stream or a desalination plant. Furthermore, they often don't care whether water is supplied by a municipal utility, a community group or their own private well. What they want is reliability and access. While this is a very utilitarian perspective, the objective in stating it so bluntly is to emphasize the substitutability that is often present within interlinked systems and the fact that such substitution can support resilience in 'macr-systems' despite the winnowing failures of sub-systems.

Attributes related to productivity and resource distribution can be defined and measured in ways that are much more precise (although also limited) than those emerging from other definitions.

## SYSTEM DYNAMICS

Having explored some of the issues related to definitions of resilience and adaptation some of the basic concepts of dynamics in socio-ecological systems are important to understand before proceeding to the more specific applied topic of adaptation to climatic variability and change.

Observations across a wide variety of ecological and human systems indicate that underlying dynamics are similar and follow consistent patterns of growth, conservation, release and reorganization. These patterns are displayed in the accompanying diagram developed by the Resilience Alliance.<sup>3</sup> During the ‘r’



growth phase entities (whether organizations, economies or organisms) exist in a resource rich environment and expand rapidly. Expansion eventually leads to increased competition as resources (energy, nutrients, commodities, money, etc...) become scarce or locked up by existing entities. This leads in the ‘K’ conservation phase to organizational patterns that are increasingly efficient and specialized but generally less flexible. The system becomes more and more structured - and momentarily predictable - as entities specialize to capture any resources that remain available and to hold on to the resources they have already accumulated. Increasing efficiency and specialization reduce flexibility and the resilience of the system to external disruption declines. At some point, external disruptions exceed system resilience and, during the “Ω” release phase, fundamental change (which is often equivalent to destruction) occurs. This fundamental change, while destructive, is also creative in that it frees resources previously captured by the highly structured and rigid components in the prior system phase and makes them available for a new phase of reorganization ‘α’ leading to another phase of creative growth as the system proceeds in an endless loop.

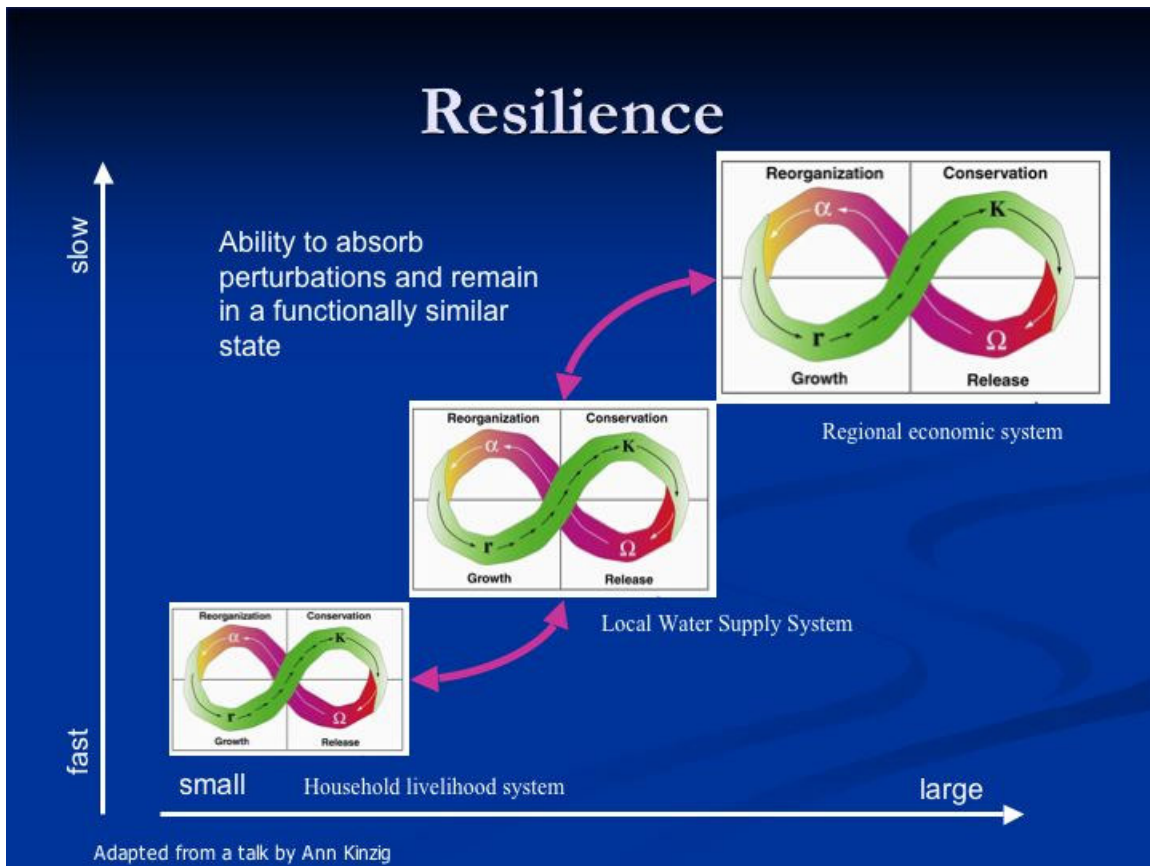
System dynamics following the above general pattern occur at different rates in different systems and are interlinked across scales and levels of organization in what Gunderson and Holling term a ‘panarchy’ (Gunderson and Holling 2002). The ‘r’ and ‘K’ phases tend to be slow and the “Ω” phase rapid, It is often the interaction between scales or rates of change in interlinked systems

<sup>3</sup> [www.resilience.org](http://www.resilience.org)

that create disruption within any given system. Furthermore, impact of the release phase of creative disruption both within and across levels depends heavily on the nature of the disruption and the status of the system. Small frequent disruptions within any given level (or subsystem) encourage the maintenance of flexibility and don't allow higher level systems to become so structured that major collapses across levels occur. Conversely, the scale of destruction accompanying the release phase tends to be much larger when systems have been shielded from more minor disruptions and have, as a result, become structured to the point where rigidities both within systems and between system levels. Systems that are tightly coupled between levels and where there is little substitutability in the functions played by key subsystems generally have low levels of resilience. Conversely, where diverse sets of subsystems play similar roles in the functioning of higher-level systems (i.e. the degree of structuration is lower) the overall system is less sensitive to disruption within any given sub-system.

In sum, nature of creative destruction is heavily dependent on the degree of structuration that has occurred in the r-k growth to conservation phase. The more structured a system has become and the greater degree to which 'redundant' sub-systems have been winnowed out, the greater the destruction that occurs when any particular component system fails. When systems are constantly responding to small destructive events across a variety of levels the degree to which they become rigidly structured is limited by continuous processes of release and reorganization - that is to say adaptation. In essence, disruption maintains diversity and redundancy in sub-systems thus reducing the degree to which higher level system functioning is tightly coupled to the specific conditions in any given sub-system. As a result, systems that are subject to continuous low levels of stress tend to be much more resilient, much less subject to fundamental reorganization, when surprise events occur.

What does this mean in practical terms? As the diagram below illustrates, the above process of growth, conservation, release, and reorganization would, for example, be occurring at the household, livelihood system, village and regional economic levels within any given agricultural economy.



## THE CASE OF GROUNDWATER IN SOUTH ASIA: AN EXAMPLE

To illustrate the implications of system dynamics in a tangible manner, take the case of groundwater irrigation in South Asia.

The dynamics of regional groundwater systems often operate on time scales that are, by human standards, very slow. In reference to the above diagram, the groundwater system would be represented as an even larger, slower moving, cycle above the regional agricultural economy. In many areas groundwater in aquifers has accumulated gradually over tens of thousands of years and, prior to human development, existed in a quasi-steady state where annual inflows were balanced by outflows. The introduction of energized pumping into the agricultural economy changed that. From the perspective of the slow moving groundwater system this was an external disruption in a previously stable set of relationships within the panarchy. It involved the release of accumulated resources and, in many areas, created a fundamental change in the dynamics of regional hydrological systems. Energized pumping technology enabled release of a resource (water) that had been locked in aquifers for millennia and made it available to the regional agricultural economy as a new highly reliable source of irrigation.

Access to new pumping technologies had a dramatic impact on the location of water resources within the agricultural economy - a new resource had become available and agriculture expanded to capture it. In India, the number of energized wells grew from an estimated 3000 at the time of independence in 1949 to over 20 million today. The irrigation economy, a relatively fast moving system in comparison to the groundwater system, expanded rapidly over a period of a few decades in the resource-rich groundwater environment. In locations such as Gujarat, a highly flexible migratory herding economy transitioned rapidly first to settled agriculture and then into intensive crop production for the market. Reliability at the level of water supply systems increased dramatically. Groundwater levels, however, began to drop and competition over access to groundwater increased. In response, the agricultural economy has become increasingly efficient. Crops have shifted from water intensive sugar cane, rice and cotton of the early irrigation period to much higher value, lower water intensity crops such as oil seeds. The number of crops that are economically viable has declined as water availability has become a limiting factor. Operations at the household and water systems level have become increasingly specialized and structured. Dairy and oil processing cooperatives have grown and now represent vertically integrated corporate marketing structures. Now returns often depend on value added (oil seeds processing and dairy products) rather than the core value of the agricultural commodity. Specialization is occurring across many scales an increasingly structured agricultural economy. It is also occurring in the irrigation system itself as farmers have moved away from open channels to pipes and sprinkler or drip systems.

Within the agricultural economy, the growth of groundwater irrigation has enabled farmers to accumulate resources (financial capital, education, etc...) and led to substantial declines in poverty across South Asia (Moench 2003). The agricultural system is, however, not stable. As water levels in aquifers decline in arid areas the assured water supplies on which intensive agriculture has grown become less reliable. Now those who can afford to deepen their wells each year and live in areas with access to deep productive aquifers have maintained access, those who can't are being forced to shift. Many farmers are forced to depend more and more on annual precipitation, Disruption is entering from both ends of the scale spectrum - the very fast moving localized weather system and depletion occurring in the very slow moving groundwater system. Fluctuations in rainfall, particularly extended periods of drought, are times of crisis. During these crises, accumulated financial and other resources are often invested in activities such as the deepening of wells where, if successful, allows farmers to maintain essentially the same agricultural system. The system is, in this case, resilient - but the resilience is only temporary because of the on-going regional groundwater overdraft process. Where farmers are no longer able to maintain access to groundwater or view further investments in wells as unlikely to be productive, they invest in migration or

the development of non-agricultural activities that represent fundamental structural changes in both the household livelihood system and the regional economy. A fundamental process of release and reorganization, that is to say adaptation, is occurring. If, as scientific consensus now suggests, climatic change is occurring the nature of this adaptive process will intensify. Increased variability within the weather system will exacerbate pressures already present due to groundwater depletion and natural variability. The difficulty in maintaining a regional agricultural system that is already in many locations unsustainable will increase the need to adapt.

## INSIGHTS FROM THE FIELD

The above groundwater example illustrates in a preliminary manner how adaptation is occurring in response to droughts and the on-going process of groundwater overdraft. But what is it that people really do? What enables or constrains successful adaptation? These are the questions that must ultimately be answered as climate change processes undermine the predictability and reliability of hydrologic systems and interact with other major socio-economic change processes. This section explores in detail insights generated through our own work on floods and droughts in South Asia and work by others from diverse locations around the world.

What do local people ‘do’ in response to floods and droughts? Perhaps surprisingly, research recently undertaken through the Adaptive Strategies Project (Moench and Dixit 2004) indicates that their responses to both are often similar. In both cases households attempt to protect existing core assets and diversify sources of income away from vulnerable activities such as agriculture. Specific strategies include:

1. Investing in education as a proactive (and often very long-term strategy) for moving one or more family members into non-farm jobs;
2. Migration and commuting to obtain access to jobs in the non-farm sector or in areas that are less affected by a particular flood or drought event. In many cases there is now a continuum between migration and commute based strategies. When jobs are available within a daily commute distance (in India now as much as 60km), people often return to home locations on a daily or weekly basis. In other situations they ‘migrate’ for periods of a month or a season. Finally, in some cases family members move on a permanent basis. As India becomes an increasingly ‘peri-urban’ society, migration is not just a rural-urban phenomenon and instead represents a web of movement between urban regions, towns and villages. Income from migration and commuting comes into households either directly (when families reside in the same location) or as remittances.

3. Developing non-farm business activities that, in many cases, complement established agricultural sources of income and, in some cases, replace them.
4. Investing in forms of infrastructure that reduce vulnerability to floods and droughts. The case of investments in wells for groundwater irrigation already discussed above is a prime example. Other examples from our research include the development of secure refuge locations in flood affected areas and secure domestic water sources in drought areas.
5. Participating in community or group institutions (such as co-operatives, regional markets and self-help groups) that help families obtain access to key financial and other resources that mitigate the impact or ease recovery from flood and drought events.
6. Cultivating social networks as a mechanism to ensure access to key financial and other resources.

None of the above strategies can be pursued by households acting in isolation from supporting institutional, financial, communications and transportation infrastructure systems. Education, for example, requires access to quality schools. Development of non-farm business activities requires transport, access to credit and the ability to communicate with suppliers and customers. The ability to migrate or commute depends on access to financial resources - the money for transport and to meet subsistence requirements while searching for a job - and is eased by the presence of reliable communications systems. Participation in community and group institutions, at least those that are formally recognized, requires enabling legal frameworks - it can be impossible to establish a bank account for a self-help group if such groups aren't legally recognized.

The importance of each of the above factors and the roles they play in adaptation and livelihood resilience is best illustrated by example. As a result, the next sections provides brief case examples from flood and drought affected areas.

#### **ADAPTATION TO DROUGHT IN GUJARAT & RAJASTHAN**

Between 1999 and 2003 much of Gujarat and Rajasthan faced an intensive period of drought. While these regions are arid or semi-arid even during normal years, precipitation in many locations was far below normal. In 2002 according to situation reports prepared by the UN, rainfall through mid-August (the end of the monsoon) totaled only 385 mm as against average annual

rainfall of 852.68 mm for the entire state.<sup>4</sup> In Mahesana district, one of the case study regions for our Adaptive Strategies project, precipitation totaled only 24% of normal levels. Similar deficits were present across most of the northern portion of Gujarat and Rajasthan.

As a result of the extended drought, agriculture in many regions declined substantially. The situation in Bhanavas, one of the case study villages in Satlasna taluka of Mahesana District, illustrates the situation well. Research in this area was undertaken by VIKSAT, a core partner in the Adaptive Strategies Project (Moench and Dixit 2004), and results presented here are drawn from fieldwork undertaken by them.

As the drought took hold in 1999 production declined substantively from normal levels during the previous year (1998) and then stopped for many crops. As the table below indicates, during 2000 and 2001 only millet, a subsistence and fodder crop, was cultivated and all agricultural production for the market stopped.

| Years Crops                   | 1998 | 1999 | 2000              | 2001              | 2002              |
|-------------------------------|------|------|-------------------|-------------------|-------------------|
| <b>Monsoon (Kharif) crops</b> |      |      |                   |                   |                   |
| Groundnut                     | 100% | 50%  | Did not cultivate | Did not cultivate | Crop failed       |
| Cluster beans                 | 100% | 30%  | Did not cultivate | Did not cultivate | Crop failed       |
| Maize                         | 100% | 50%  | Did not cultivate | Did not cultivate | Crop failed       |
| Minor millet (Bajra)          | 100% | 70%  | 50%               | 25%               | Crop failed       |
| <b>Winter (Rabi) crops</b>    |      |      |                   |                   |                   |
| Wheat                         | 100% | 50%  | 25%               | 10%               | 5%                |
| Mustard                       | 100% | 50%  | Did not cultivate | Did not cultivate | Did not cultivate |
| Tobacco                       | 100% | 10%  | Did not cultivate | Did not cultivate | Did not cultivate |

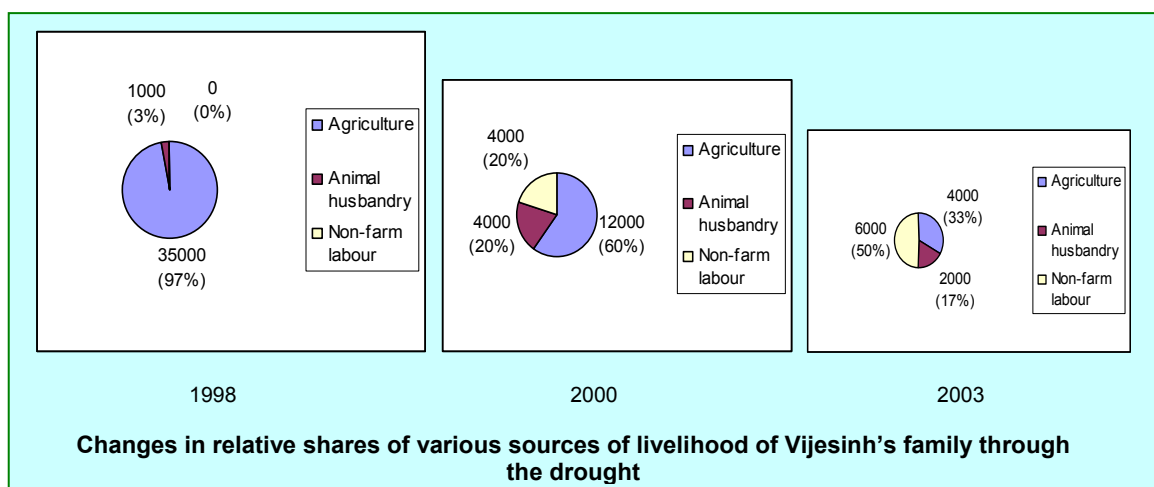
As crop production declined, people invested available funds in the deepening of existing wells and drilling new bore wells in a generally fruitless attempt to maintain access to groundwater. They also increased their reliance on animal husbandry. In some villages milk production actually increased during the drought as villagers concentrated available resources on dairy. This was made possible by concentrating available water resources on fodder production and, when that proved insufficient, purchasing fodder. In addition to increased reliance on animal husbandry most families sought out opportunities for wage labor. In the Satlasna region, where our fieldwork was conducted, activities included:

1. Migration for wage labor to other adjacent areas where extensive access to groundwater enabled farmers to maintain agriculture despite the drought;
2. Migration for construction and other work in urban areas and adjacent towns in the region;
3. Working on a daily basis polishing diamonds in small units located in towns and the district headquarters; and

<sup>4</sup> [www.un.org.in/UNDMT/sitrep/drought/ Gujarat---Drought---SitRept200802.doc](http://www.un.org.in/UNDMT/sitrep/drought/Gujarat---Drought---SitRept200802.doc)

#### 4. The development of small-scale business activities.

For many families the process of responding to the drought resulted in substantial declines in income and the standard of living. Prior to the drought in Satlasna, less than 10% of the population was below the officially recognized poverty line, by the last year over 60% were. The change in livelihood structure is illustrated well by the case of Vijesinh's family. As the diagram below illustrates, from almost complete reliance on agriculture in 1998 and a substantial household income of Rs 35,000, by 2003 non-farm labor accounted for 50% of all income and agriculture only 33%.



Not all farmers were as badly affected by the drought as Vijesinh's family. In almost all villages some families maintained or increased income levels throughout the drought period. In many cases these were families with members who were already working in non-farm activities or held formal postings with the government. Families who were better positioned to increase dairy production because they had access to secure sources of water also did relatively well. Furthermore, in some cases villagers had developed livelihoods specifically because of their ability to respond to droughts. This was, for example, the case in two villages where research was conducted under the Adaptive Strategies Project by the Institute of Development Studies in Rajasthan (Moench and Dixit 2004). Farmers in one village had developed a major woodworking and furniture construction business - despite the fact that this was inconsistent with their caste status. In the other village, farmers had diversified into ice-cream production. This utilized their existing contacts with other farmers and focused on a product that is virtually guaranteed to do well during the hot dry conditions characteristic of drought-affected areas.

The ability of households in drought affected areas to adapt or cope with drought in Gujarat and Rajasthan was affected by many factors. In the

Satlasna area, the ability of many farmers to increase milk production was enabled by:

1. The presence of transportation systems for both fodder and the milk itself;
2. The presence of effective communications systems that enabled farmers to identify potential sources of fodder;
3. The presence of regional dairy cooperatives that provided a mix of services including credit, milk processing and the ability to purchase fodder in bulk.

Where diversification into non-farm livelihoods was concerned, social networks also played a central role. Familiarity with regional labor markets enabled many of the smallest farmers to maintain living standards better than their initially more well-off neighbors. These small farmers had to depend on wage labor for part of their income even in normal years. As a result, they were better positioned than farmers who, although better off, had little experience with regional labor markets. Similar social networks appear to have played an equally important role in the ability of individuals to enter other activities. In the ‘ice cream’ case for example, one enterprising individual went as an apprentice to an ice-cream maker over a decade before the drought. He then introduced other individuals to the business. At that stage each of the individuals had resources available to invest and could either purchase directly or obtain loans for the equipment needed. A similar story underlies the case of diversification into woodworking. Knowledge of the business obtained through social networks was a critical catalyst along with access to the financial resources required for investment.

#### **ADAPTATION TO FLOODS IN EASTERN UTTAR PRADESH, BIHAR AND THE NEPAL TERAI**

In Eastern Uttar Pradesh, Bihar and the Nepal Terai the impacts of flooding in the Gangetic Basin are as devastating as the drought is in Gujarat and Rajasthan. Floods occur on an annual basis with large scale ones occurring in some cases several times each decade.

While flooding is a natural phenomenon in the region, the impacts have been exacerbated by human activity. Roads, railway lines and embankments now impede drainage in many parts of the basin. As a result, according to villagers in case study locations, water logging has become a major problem. Where flooding once persisted for a few weeks, now water can remain for months. Furthermore, in the case of embankments, protected areas are threatened by sudden levy breaks and even under the best of circumstances villages between the embankment and the river become flooded.

What are people doing in response to recurrent flooding? Research conducted by our partners in villages along tributaries to the Ganges indicates that, as in

drought-affected regions, the diversification of livelihoods into non-agricultural activities is a cornerstone strategy. Because opportunities for this are limited in some areas such as Bihar, out-migration in search of work from those regions is high. Much of this is long-distance with individuals traveling to other states as agricultural labor. In addition, villagers are developing micro-enterprises wherever possible.

Remittances and funds brought by returning migrants are one of the main sources of income for many families during floods. These are used both to meet immediate needs and, in many cases, for further income diversification (starting a small business, education, etc.) and the construction of flood resilient housing.

The housing example provides a particularly tangible example of adaptation. For the poor, houses have throughout history been constructed primarily of mud and straw. Now, in many areas families having the resources to do so invest in houses where at least one room is constructed out of brick and has a high flat roof. Such structures provide a point of refuge for family members and, equally if not more importantly, a location where key assets - rice, farm machinery, a sewing machine, a bicycle, etc...-- can be protected from flood waters. A high flat roof is an asset protection platform. Without it accumulated assets are lost in each cycle of flooding and families have little opportunity to move out of poverty. Access to this simple structure enables people to reduce losses and, with luck, begin a process of accumulation that may ultimately move them out of poverty. It is similar to other community-based risk reduction strategies, such as the building of mounds where villages can be constructed, that seek to protect assets from floodwaters. Construction of flood resilient housing is, however, much more of a family based strategy. The ability to undertake it depends on access to external sources of income - typically remittances - that are under the control of individual households. Raising the level of villages, however, requires either the presence of community institutions with substantial financial resources or government programs. While some such initiatives exist (the Government of Uttar Pradesh has raised the level of 4511 villages), they are small in relation to the overall scale of flooding.

The household and community level asset protection - refuge strategies are fundamentally different from attempts to regulate rivers using embankment and reservoir systems. The ability to 'regulate' rivers requires the ability to predict with a high degree of precision both high flood and low flows in order to design channels with, respectively, sufficient capacity and the ability to flush sediment. In contrast, the creation of refuges requires only an ability to predict flood levels. Since flood levels are relatively insensitive to volume, a refuge based approach is much more resilient in the face of uncertainty than attempts to regulate flood volumes. Furthermore, the regular occurrence of small floods encourages people to avoid areas that are particularly vulnerable

to flooding and, where that isn't possible, to build resilient houses in vulnerable areas. When areas are protected by embankments, however, the incentive to do this is far less and the impact of flooding when embankments fail (as they often do) is far greater. When embankments fail, in fact, the large volumes of water released often increase flood depths and the scouring power of concentrated flows to the point where refuge based systems no longer provide much protection. Refuge systems are, as a result, particularly effective in conjunction with large-scale drainage activities and techniques that avoid concentration of flood flows in any given location.

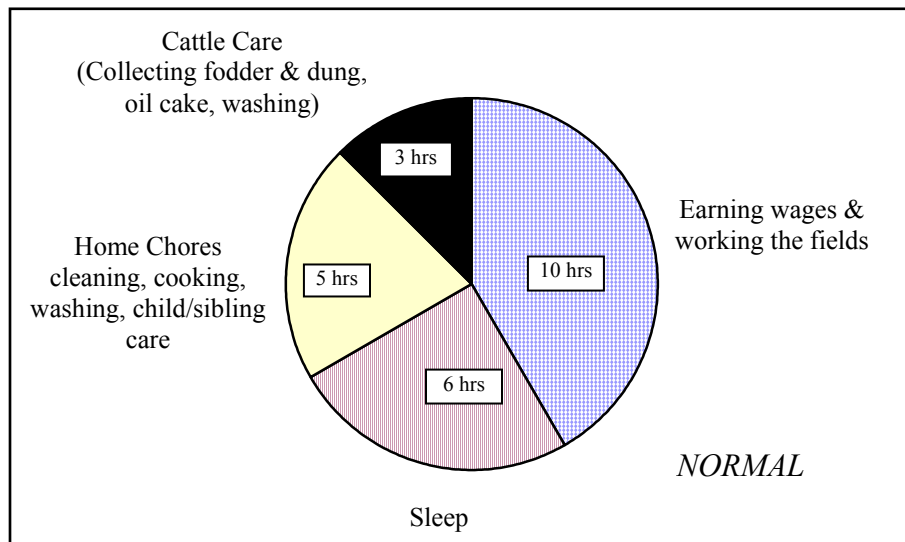
The difference in effectiveness between strategies focused on river regulation and strategies emphasizing refuge is likely to be particularly great in the context of climate change. The prediction of flood volumes (and thus the ability to design embankment and reservoir systems) requires long periods monitoring in order to develop sufficient data to characterize the hydrologic system. When this system is itself changing then predictions based on historical conditions may have little relevance for the future. As a result, approaches, such as refuge based strategies, that are robust under uncertainty are likely to be more effective than strategies, such as river regulation, that only function within a relatively narrowly constrained set of flow conditions. As discussed further in the section on Integrated Water Management below, this example illustrates a fundamental difference between 'adaptation' focused approaches and much current water management thinking.

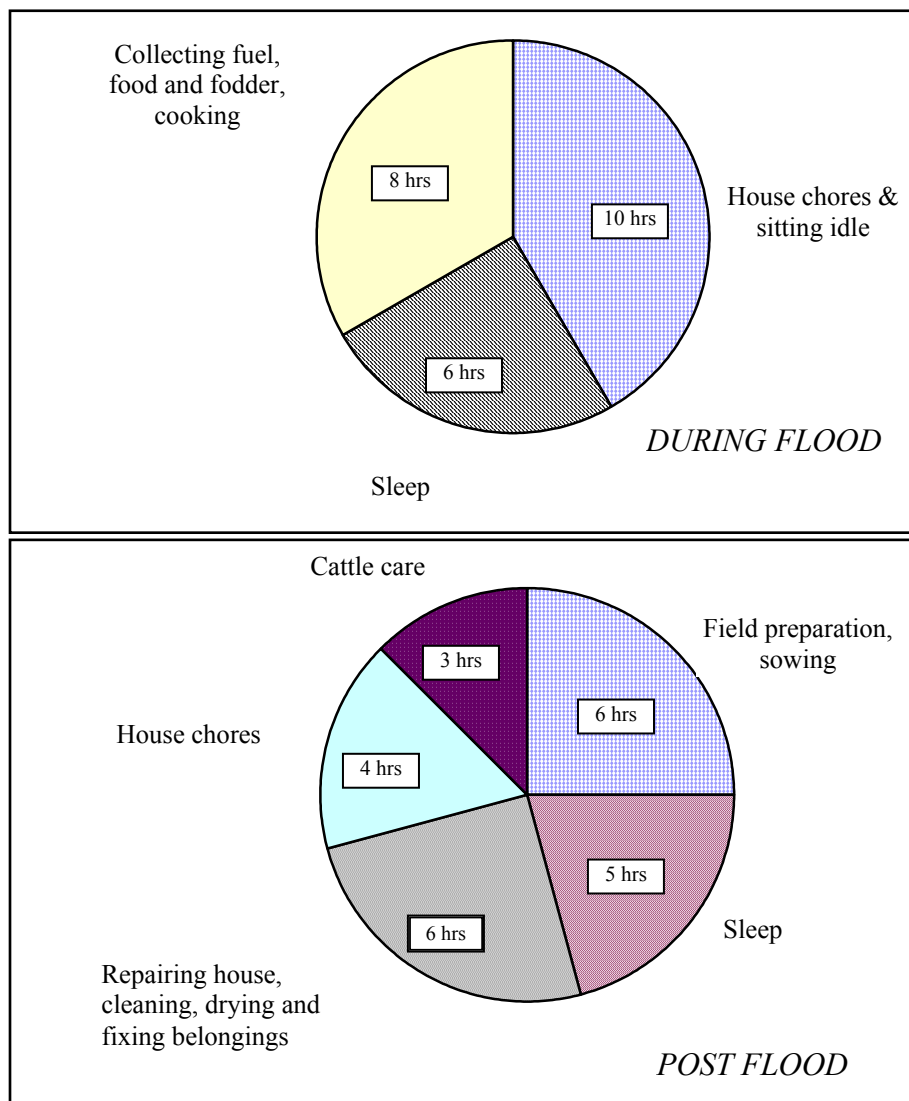
As with household responses to flooding, the factors that constrain and enable people's ability to adapt to are similar to the drought case. Migration and diversification require financial resources. Families that lack the resources to invest in education or even to afford the costs of migration in search of wage labor are the most affected by flooding. Institutions and social networks play a huge role. In parts of the Nepal Terai, such as Makar village along the Rohini River (a tributary of the Ganges and a case location where research was undertaken as part of the Adaptive Strategies Project by Nepal Water Conservation Foundation (Moench and Dixit 2004)), access to a diverse network of government, non-government and private sector organizations including financial institutions has created a support network and ability to diversify that is notably absent in the far more vulnerable region of Paurai on the Bagmati river. Financial institutions represent an important component of this. In some areas, banks provide loans for non-agricultural activities and access to credit from formal sources can be obtained. In other areas, however, formal sources of credit are only available for agricultural activities (crop loans, etc.) and are difficult to access. In such regions people depend primarily on private moneylenders to support the cost of migration or the development of non-agricultural business activities and the cost of credit represents a major constraint on the ability to diversify. Transport is also important. In many regions, floods limit the ability of people to move about and transport food or other commodities. This limits their ability to maintain livelihood systems

during floods. Similarly access to information is a limiting factor. In most areas the only information available on flood prospects arrives by word of mouth or is identified through direct observation of weather patterns.

The above constraints have a differential impact on discrete social groups. Women in Eastern Uttar Pradesh and Bihar typically have far less ability than males to migrate to obtain access to wage labor, have less access to organizations or financial institutions and do not control family assets. They also tend to have far greater direct responsibility for children and the provision of labor for recovery following floods within family systems. As a result, the impact of flooding tends to fall disproportionately on women. This is clearly illustrated by workload information collected by Ghorakpur Environmental Action Group as part of village level surveys in the Bihar and Uttar Pradesh case study areas (Moench and Dixit 2004). As survey results summarized in the diagram below show, not only does the workload increase following floods but access to income sources that are under control of the women, principally wage labor within village areas, declines. As a result, women lose control over resources to a much greater extent than their male counterparts.

#### *WOMEN'S WORKLOAD BEFORE, DURING and FOLLOWING FLOODS*





As local partners from the case area emphasized, given the extent of male out-migration in all study areas, building resilient community adaptive systems will need the simultaneous strengthening of women's leadership roles and livelihood capacities. In addition, this approach cannot be divorced from the articulation of women's fundamental human rights, which are all too often violated in a disaster context.

What are the existing governmental responses to flooding in the Ganges basin? In Nepal the government has played a minor role in both flood mitigation and related disaster relief. In India, however, most investments have focused on the construction of embankment and drainage systems. By 2000, across India the government had constructed over 33,600 km of embankments and an additional 37900 km of drainage channels (Ministry of Water Resources 2000).

In Bihar alone the state government currently has proposals for flood control related activities that will cost an estimated 5420 million rupees.<sup>5</sup> In addition, the government is investing huge amounts in disaster relief. The total funds released for floods, droughts and weather related disasters between 1999 and 2002 totals almost 21,000 million rupees (\$488 million at the current 43 Rupee/\$ exchange rate).<sup>6</sup> Of this over half was related to flood and storm related issues in the Gangetic basin and adjacent regions.

The contrast between governmental strategies and those followed by local populations in flood-affected regions is important to recognize. The strategies households have developed for adapting to floods emphasize income diversification and the protection of family assets by creating points of refuge. Governmental strategies, in contrast, emphasize regional flood control and disaster relief. Both sets of approaches face major constraints and leave groups, such as women, in vulnerable positions. Household strategies require access to financial and other resources, such as education, in order both to develop low-vulnerability income sources, to support pro-active migration and to construct flood resilient housing. They also require access to rapid communication systems both for early warning and as a core part of the infrastructure necessary for effective diversification. Governmental strategies are constrained by cost and ‘unruly nature’ - the embankments and flood control measures have limited effectiveness in the context of significant climatic variability and change. Furthermore, disaster relief often recreates patterns of vulnerability. At present there is little support by the government for the types of activities households and communities either are or could undertake to adapt to flooding.

#### **ADAPTATION TO LONG-TERM WATER SCARCITY IN YEMEN**

Yemen is an inherently arid region where annual averages range from a high of 700mm in a few locations such as Ibb to large areas where precipitation averages 300 mm or less. Variability both within and between years is high. Furthermore, as in parts of India, the already limited availability of water has over recent decades been compounded by extensive groundwater overdraft.

Groundwater extraction exceeds recharge in most regions (see table 1). The Highland Plains aquifers, are particularly threatened because groundwater extraction greatly exceeds recharge and overall storage levels are low. Furthermore, regional estimates such as those in Table 1 (WRAY-35 1995) understate the magnitude of emerging water problems since water stored in aquifers such as the extended Mukalla Complex, while sufficient to meet the domestic needs of a large population, would be both expensive to develop and rapidly depleted if used for agriculture.

<sup>5</sup> Smt. Bijoya Chakroborty, Minister of State for Water Resources replying to a question asked by MP Laloo Prasad Yadav, Rajya Sabha, Unstarred Question No 3377, 22.04.2003

<sup>6</sup> Lok Sabha Unstarred Question No. 3324, dated 06.08.2002 - [www.IndiaStat.com](http://www.IndiaStat.com)

| Aquifer Complex                           | Approximate abstraction (Mm <sup>3</sup> /yr) | Approximate average recharge (Mm <sup>3</sup> /yr) | Fresh groundwater stored (Mm <sup>3</sup> ) |
|---|---|--|---|
| Tihama Quaternary Aquifer                 | 810   | 550  | 250,000                                     |
| Southern Coastal Plains (west of Mukalla) | 225   | 375  | 70,000                                      |
| Extended Mukalla Complex                  | 575   | 500  | 10,000,000                                  |
| Highland Plains                           | 500   | 100  | 50,000                                      |

Source: (WRAY-35 1995) Table 6.3, P. 88

Historically, Yemeni society has been dominated by agriculture. Even with efficiency improvements, agriculture will remain inherently water intensive. Maintaining a population, which in 1996 was growing at close to 4% annually, through agriculture in the arid environment of Yemen necessitates large and growing amounts of irrigation. But available water supplies are limited. Mining groundwater can, at best, allow a temporary continuation of current levels of agricultural activity. Ultimately, agriculture will be limited to that supportable by the renewable portion of the water resource base. While this may be sufficient to support a significant portion of the population, many current agricultural activities are unsustainable and there is little possibility of increasing agriculture in proportion to population growth. Even at present opportunities for agriculture or livestock based livelihoods are severely constrained and only a portion of the population are able to derive their subsistence from them.

How have Yemeni's adapted to water scarcity and the inherent variability of precipitation events? Within agriculture, farmers have a long tradition of techniques such as spate irrigation that are designed to work with variability and make use of limited available water sources as they become available (Vincent 1990). Spate systems are, in fact, highly adapted to both variability and the extreme nature of flash floods common in the countries arid wadis (International Fund for Agricultural Development). They are designed to enable farmers to divert sufficient water for their fields without blocking the main flow and, as a result, being washed away under the extreme erosive force of a typical flashflood. In addition to adapted diversion structures, except where perceptions of unlimited availability have been introduced through

groundwater development, high value crops (particularly Qat) irrigated using relatively efficient drip and sprinkler based technologies are common. In addition, as in India, households have attempted to diversify out of agriculture. Unlike India, however, aside from agriculture Yemen has a very narrow economic base. As a result, opportunities for diversification into non-agricultural activities within the country are extremely limited. As a result, Yemen has historically depended heavily on trade and migration - including the world. This changed following the first Gulf War in 1991 when the Government of Yemen's support for the Saddam Hussain government in Iraq led to the expulsion of Yemeni workers from many surrounding countries. This has created severe economic hardship. It also directly affects the adaptive capacity Yemeni communities in a way that illustrates key links between adaptation processes at local levels and the ability access external resources via migration. This linkage is illustrated below through the case of al Sinah, a village in the Ta'iz region. This case was prepared as part of the Decentralized Management Study, an input to the World Bank's water strategy for Yemen (Moench, Lackner et al. 1997).

### **The Administration of Local Projects in al Sinah**

In the Ta'iz region, the limited availability of water for agriculture and absence of other economic opportunities has created strong incentives for migration throughout most of recent history. Ta'iz is well known for its highly educated population and during the 1960s and 1970s many workers from the region found employment in neighboring countries and major cities within Yemen.

In 1975, emigrants from al Sinah in Saudi Arabia and Abu Dhabi along with the cities of Sana`a, Taiz and Hodeida, started to create formal welfare associations to support of their local community. The initial project in Al Sinah focused on domestic water supply and the originator, Abdo Naji Muqbil, traveled to Saudi Arabia to inform the emigrants of the community's plans and collect funds. The first phase of this project was strongly supported by the local community, particularly women who sold their gold and other possessions as contributions. Before the project they had to walk up to 7km distance and 700m uphill to bring water to their homes. When it was finally implemented using a combination of funds donated by migrants, community donations and governmental support the initial network brought water to water tanks installed outside the community school, and women then collected water in the traditional way, in jerrycans borne on their heads. In 1980 the network was extended from distribution tanks at the school site to the center of each hamlet where a tank was installed. People in the community were asked to contribute towards the running costs of the project according to their means.

By 1983 all the hamlets in al Sinah were connected and the organization started to install standpipes for every house, with a meter at the tap. House

connections were not made to avoid the buildup of stagnant water in the houses and yards. In 1985 the water in the original wells dried up. Other sources of water were sought and despite some opposition from the neighboring `uzla's traditional leaders were ultimately possible to develop. Agreement on the new wells was reached because the water was for drinking and not irrigation purposes (a use which can not be blocked under the 'right of thirst' in the Shari'a). In 1996 1200 houses were supplied with water. Most families pay according to use with a minimum fee of YR 250 per month for each service. Roughly 250 poor households are supplied free of charge. Supplies have become irregular as a result of frequent breakdowns of the equipment. The wells are, however, still functioning, and in 1996 an additional tank of 150m<sup>3</sup> was being built.

An important aspect of al Sinah's water supply scheme is its efforts to protect the source. Local communities recognize well spacing regulations that prohibit new wells within 500m of existing wells. As a result, when they installed their new well field, al Sinha bought plots of land in the wadi and drilled wells at intervals of 500m.

In addition to the water supply scheme, the Administration of Local Projects in Al Sinah runs a major school that provides education to approximately 3000 students, has built roads and provides electricity to approximately 1200 households.

Despite its relative success, the Administration of Local Projects in al Sinah faces serious financial difficulties due to the drying up of income opportunities from international and internal migration, rampant inflation and a total lack of local possibilities for non-agricultural income generation. In addition, governmental support for local organizations of its type was weak at best. In many cases such organizations have been perceived as a political threat because of the tangible support they provide to communities.

The case of al Sinha illustrates a number of key factors that influence the ability of communities to adapt to climatic variability and change. Three of the most important are:

1. The right and ability of local people to organize. As well as the actual implementation process, the existence of a strong, respected and trusted local organization was a critical factor underlying the willingness of migrants to contribute finances to community projects.
2. The role of migration and remittances: Without the ability to migrate and send remittances home key adaptive activities including the local water supply project and the school (a training ground for future migrants) would have been impossible to implement. Now that

remittances have declined and migrants have been forced to return, the adaptive capacity of the local population has been severely affected.

3. The limitations of water management *per se*: While the local community could reach agreement with neighbors regarding the right to domestic water supplies, this did not apply to irrigation water. As climatic variability increases it may be possible in many areas to meet domestic water need, but impossible to maintain agriculture.

Diagram 1: Water Market Structures<sup>7</sup>

| <b>Rural Irrigation Well Water Market Structure</b>   |   |  |   |
|---|---|--|---|
| <b>Producer</b> -----><br>Well owner<br>Cost <sup>8</sup> to pump =<br>YR 0.43/m <sup>3</sup> | <b>Consumer</b><br>-- share cropper<br>-- hourly rate<br>equivalent to<br>YR 2-4/m <sup>3</sup>   |  |   |
| <b>Tanker Water Market Structures</b>   |   |  |   |
| <b>Producer</b> -----><br>Well owner<br><br>Cost to pump =<br>YR 0.43/m <sup>3</sup>          | <b>Consumers who have their own transport</b><br>-- industry<br>-- hotels<br>-- poultry farms<br>-- agriculture<br>Rate avg. YR 14/m <sup>3</sup> |  |   |
| <b>Producer</b> -----><br>Well owner<br>Cost to pump =<br>YR 0.43/m <sup>3</sup>              | <b>Retailer</b> -----><br>Tanker truck owners<br>Rate avg. YR 14/m <sup>3</sup>   | <b>Consumers</b><br>-- individual homeowners<br>-- hotels/restaurants<br>-- industry<br>-- construction<br>-- agriculture<br>Rate avg. YR 210/m <sup>3</sup> |   |
| <b>Producer</b> -----><br>Well owner<br><br>Cost to pump =<br>YR 0.43/m <sup>3</sup>          | <b>Wholesalers</b> -----><br>Treatment Plants<br><br>(generally have their own transport)   | <b>Retailers</b> -----><br>Shops   | <b>Consumers</b><br>Individuals/families<br>Rate up to YR 2000/m <sup>3</sup> for purified drinking water |

This last point is important to elaborate on a bit further. In many locations across many Yemen extensive water markets have developed that effectively

<sup>7</sup> Prices as of January, 1996. At that time the exchange rate was approximately YR 86/\$ on the black market and YR 25/\$ on the official market.

<sup>8</sup> Cost based on fuel and maintenance estimates. Does not include capital cost for pumps and wells

reallocate available supplies both within agriculture and from agriculture to urban needs. The structure of one such market in Ta'iz is illustrated below.

Institutions such as the above informal water market are highly flexible and often operate in parallel with social norms such as the 'right of thirst' that guarantees all living beings access to water under the *Sharia'a* (Wescoat 1995; Faruqui 2001; Moench 2001). They enable rapid reallocation of available water resources but they have little to do with management of the water resource base. While traditional systems such as the spate irrigation techniques that are widely used across Yemen do involve management of the resource base, very few examples exist of management similar to the source protection activities undertaken in al Sinha. Overall, systems for allocation of available resources are common while systems for actually managing the resource base are much less so. This is also the case across water scarce portions of India.

#### SUMMARY OF INSIGHTS FROM THE FIELD

The above case examples highlight a variety of factors that enable and constrain effective adaptation to climatic variability. In virtually all situations livelihood diversification represents a central element in the adaptation process. This has also been a central finding in other research on adaptation. As Folke *et al* point out, "Diversity is not just an insurance against uncertainty and surprise. It also provides a mix of components whose history and accumulated experience helps cope with change, and facilitates redevelopment and innovation following disturbance and crisis" (Folke, Carpenter et al. 2002). Particularly where local opportunities for diversification are limited, the cases explored here show that diversification was often achieved by proactive migration or commuting strategies. As other studies in areas as diverse as Asia, Africa and the Arctic have also found (Hussein and Nelson 1998; Berkes and Jolly 2001; Brown 2005), migration often isn't a function of immediate distress undertaken as a consequence of disaster, instead it is often a proactive diversification strategy. The ability to diversify in this manner, and also through the development of non-agricultural activities in home locations, depended in turn on access to the financial resources, communications systems, transport infrastructure, social networks, education and information. In most situations, adaptive capacity within home locations depended heavily on a combination of local factors and external linkages. The presence of trusted local institutions (such as the Administration of Local Projects in al Sinha) served as a nodal point for migrants to invest remittances in activities within their home communities. Where such institutions are absent, remittances flowed primarily to individual families and provided far less benefit to the local area as a whole.

In addition to diversification, adaptation and livelihood resilience involve the development of flood and drought adapted infrastructure. While this includes conventional water control structures such as dams and embankments, at the

community and household levels strategies that live with rather than involving direct attempts to manage the resource base dominate. In the flood case this consists of flood adapted housing and the spate irrigation systems of Yemen. In drought areas it consists of drinking water source protection, the adoption of efficient water use technologies and the development of informal market or other social mechanisms for allocating available supplies.

At present, adaptive responses are far from perfect. In all of the case examples large sections of the population faced fundamental constraints in their ability to adapt. In Gujarat, despite attempts to diversify, incomes declined very substantially as a consequence of the drought. This was particularly true for the previously middle-income farmers who had little prior experience in diversification. In Gangetic basin, women (and other vulnerable groups) were particularly affected. They were often constrained in their ability to diversify by social norms and lack of access to or control over the financial and other resources required. In Yemen, macro political changes, in specific limitations on migration and the ability to send remittances home, undermined previously successful attempts to adapt.

Broad patterns such as those emerging from the case locations provide important insights into the process of adaptation and the factors that contribute to livelihood resilience. It is important to recognize, however, that these patterns speak more to the underlying structural factors enabling or constraining adaptation and far less to the approaches that may or may not be appropriate in any given situation. In each of the cases, for example, local constraints and opportunities shaped the specific ways in which people adapted to floods and droughts. To put it another way, while livelihood diversification appears to be a common 'cornerstone' strategy, specific opportunities for diversification are very different in different areas. Similar comments apply to flood and drought adapted infrastructure and other components of adaptation.

#### **CONTRASTS WITH CONVENTIONAL STRATEGIES: ADAPTATION VS INTEGRATED WATER RESOURCE MANAGEMENT**

According to the Global Water Partnership (GWP) integrated water resource management (IWRM) is defined as “a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (Global Water Partnership Technical Advisory Committee 2000). Discussions of this process by the GWP and others emphasize the fundamental importance to IWRM of participation by communities and other stakeholders along with the principle of subsidiarity - i.e. that management decisions and interventions should take place at the lowest possible level. They also emphasize the interaction between institutions and management instruments within a larger enabling

environment as the fundamental factors that combine to move society towards equitable and environmentally sustainable forms of water management.

In some ways the concepts of IWRM parallel those emerging from research on adaptation and livelihood resilience. Both see human and environmental outcomes as the product of interaction between social and natural systems. Both are also process focused. The emerging field of work on adaptive management (which addresses natural and environmental systems broadly rather than the IWRM focus on water) incorporates many of the principles of IWRM. Most importantly, as with IWRM, discussions of adaptive management emphasize the dynamic nature of systems and the need for iterative approaches that can respond to continuous change processes. As a result, IWRM is, in some senses ‘adaptive’ and is intended to assist regions to develop responses to emerging water problems that respond (i.e. are adapted) to local conditions.

The above parallels, however, mask basic conceptual and even more fundamental applied differences.

Freedictionary.com defines manage as “To direct or control the use of ....To exert control over... to make submissive to one's authority, discipline, or persuasion.”<sup>9</sup> The term ‘adapt,’ however, is defined as “To make suitable to or fit for a specific use or situation...to conform oneself to new or different conditions.”<sup>10</sup> The fundamental difference between ‘controlling’ a situation and ‘conforming to’ a situation is inherent in virtually all definitions relating to management and adaptation. At a basic level, however responsive IWRM is to local conditions, the ultimate goal is to control water resources and society’s use of them in order to meet sets of socially defined objectives. Adaptation, in contrast, emphasizes the need for society to respond to the dynamic processes within systems that cannot be controlled. Adaptation is much more about processes that give society the ability to conform to and live with variability and change while management is about processes to control such variability and change. Adaptation is an aggregation of features that often occur in ways that are not planned but are emergent characteristics catalyzed by changes in underlying systems. It often isn’t ‘managed.’

The above basic difference in orientation implies fundamentally different approaches in practice. Adaptation processes ‘happen.’ That is to say, the process of adaptation is an on-going one that occurs whether or not any entity directs it. Governments and other actors can assist society to adapt in ways that support well being, environmental sustainability and the resilience of livelihoods - but the basic process of adaptation are driven by underlying changes in interaction social and environmental systems. As a result, attempts to build adaptive capacity and resilient livelihoods will need to focus on a

<sup>9</sup> <http://www.thefreedictionary.com/manage>

<sup>10</sup> <http://www.thefreedictionary.com/adapt>

diverse array of entry points where strategic interventions can contribute to livelihood and sustainability goals. While the proximate cause of a ‘problem’ may be floods, droughts or extreme weather events, the focus on adaptation may lead to the identification of interventions - such as those supporting diversification into non-agricultural livelihoods - that have little to do with water or climate *per se*.

In contrast to adaptation, practical attempts to implement IWRM concepts generally focus on courses of action that attempt to directly control water resource conditions and use. Furthermore, while organizations such as the GWP emphasize the importance of subsidiary and participation, national water bureaucracies rarely follow this rhetoric. The need for integration often supports the creation of highly centralized organizations with a mandate to undertake large-scale management projects. The proposed program to link major rivers in India is a case in point. This project is being developed under the guidance of a national level task force located within the Central Water Commission, the highest-level policy organization concerned with water in India. As described in detail on its web site,<sup>11</sup> the project is integrated in that it is designed to respond to a very wide variety of irrigation, municipal supply and other social and economic objectives. It is also clearly a ‘management’ project in that it is designed to fundamentally reshape and control the basic hydrological system within much of South Asia. As a result, it is clearly perceived by many of the institutions involved as conforming closely with the IWRM paradigm.<sup>12</sup>

The differences between adaptation and IWRM are, as a result, likely to be fundamentally different in most practical contexts. Research by organizations in Nepal and Eastern Uttar Pradesh identified livelihood diversification and the development of ‘flood adapted’ forms of infrastructure as central strategies for adapting to floods. On a physical level, this would consist of water interventions that emphasize points of refuge and drainage along with non-water related interventions including early warning, flood resilient transport systems and access to non-agricultural income sources (Moench and Dixit 2004). Adaptation, in this context, emphasizes underlying systems that support economic and social flexibility and enhance the ability of people to ‘live with’ floods. In contrast, the river-linking proposal envisions the construction of large-scale infrastructure to control flood flows and transport floodwater to other portions of the country. The goals are much more related to efficiency and the reshaping of hydrological systems in ways that reduce the importance of ‘living with’ natural system dynamics.

<sup>11</sup> <http://riverlinks.nic.in/>

<sup>12</sup> A point made by GOI representatives at the III World Water Forum, Kyoto, March 16-23, 2003.

## FROM OBSERVATIONS AND CONCEPTS TO POLICY

The case examples and contrast with IWRM above illustrate key elements of adaptive behavior in applied contexts. To identify their wider policy implications it is essential to briefly step back and link again to wider conceptual frameworks.

### CONCEPTUAL FRAMEWORKS AND OBSERVED BEHAVIOR

Financial flows are to socio-economic systems as energy and nutrient flows are to ecological systems. In both cases the factors shaping access to such flows are as important as the total amount of money, nutrients or energy stored in the system. The field observations on adaptation and livelihood resilience in flood and drought affected areas demonstrate dynamics that are, in fundamental ways, akin to dynamics in ecological systems. Diversification, the creation, identification and occupation of economic niches, is the cornerstone strategy most households and communities follow whether intentionally or not in adapting to floods and droughts. This often represents a fundamental change in the structure of livelihood systems. It is supplemented in many cases by techniques for infrastructure and institutional design that are resilient in the face of high levels of variability. This infrastructure and institutional development increases the resilience of existing livelihood systems without changing them in fundamental ways. Households and communities are, to link our field observations back to the conceptual frameworks presented earlier, undertaking courses of action that both increase the resilience of established livelihood systems and engage in fundamental systemic change when those systems fail.

Adaptive change processes and the development of system resilience appear to both be catalyzed in response to stress. High levels of climatic variability in arid environments, as illustrated in the case of Yemen, stimulate systems that contain high levels of diversification (agriculture plus access to diverse non-agricultural activities via migration) and the development of flexible and resilient systems (spate irrigation, water markets). Where variability has been 'ironed out' through the development of highly reliable water sources (groundwater in Gujarat, areas protected by embankments in Bihar) agricultural systems become far more rigid and specialized. While diversification and other changes do occur under stress when access to groundwater declines during droughts or levies fail in floods, such disasters also involve substantial declines in living standards. The  $\Omega$  release phase and ' $\alpha$ ' reorganization phases have a major impact on vulnerable populations when large-scale disruptions to systems occur. Furthermore, it is important to recognize that such disruptions can come from many sources in addition to our focus here on climate and water. The case of Yemen illustrates this well. Systems that were, in many ways, well diversified and adapted to water

scarcity and climatic variability depended for this adaptation on access to regional labor markets. When this access was cut off due to the first Gulf War, it had a major impact on the ability of local communities including al Sinah to maintain the infrastructure and institutions that enabled them to adapt to climatic and water related constraints.

In sum, taken together insights from case study locations and the larger conceptual frameworks indicated that adaptive capacity and livelihood resilience depend heavily on flexibility and the ability to diversify livelihood strategies. These, in turn, depend on access to financial and other resources and the ability of money, information, goods and people to flow across internal and international borders. Mobility is critical. Finally, adaptation is catalyzed by stress. Droughts, floods and other forms of stress provide the critical incentive for people to continuously adjust behavior. Without this incentive, livelihood systems become increasingly structured and ultimately more vulnerable when major stress occurs. Adaptation is, as a result, pulsed - droughts, floods and other times of crisis are the times when change occurs. Events such as these do stress the system - but they are also critical windows of opportunity for changes that increase resilience or catalyze adaptive responses that reduce vulnerability.

## **POLICY IMPLICATIONS**

The link between conceptual frameworks such as the above and field observations has substantive practical implications for policies on development and disaster relief in the context of climatic change. While it is difficult to isolate individual policy issues from each other, the discussion here focuses on three broad categories: 1) major transboundary policy arenas; 2) national and local policy issues; and 3) programmatic issues in development and disaster mitigation.

The discussion is, at best, partial. Perspectives drawn from systems dynamics tend to highlight cross-cutting issue areas and the links between very diverse potential arenas where policy changes are likely to influence adaptive capacity and livelihood resilience. As a result, the discussion here focuses on a limited set of cross-cutting issue areas that, rather than pretending to be comprehensive, illustrate the types of connections involved.

### ***Trans-boundary Policy Arenas***

Diversification, the cornerstone strategy followed by local populations in adapting to change, depends heavily on migration and the ability of information, goods, and finances to flow across both local and national

borders. As a result, trans-boundary policy issues related to these topics are central.

### **Migration & Commuting**

Policies related to migration and the mobility of local populations are of particular importance in relation to livelihood resilience and the adaptive capacity of local populations. In India, most disaster relief and development policies emphasize keeping local populations from migrating. During droughts and floods, migration has conventionally been taken as a critical indicator triggering relief activities - such as food for work programs -- designed to help local populations remain in place. While distress migration during crisis is often highly disruptive for local communities, proactive forms of migration and commuting are often a core component of the adaptation process that can increase the resilience of local livelihood systems. Furthermore, as the case examples document, access to external labor markets often provides the resources required to develop or maintain resilient livelihoods within home locations. Migration and commuting provide a dual benefit. They remove a portion of demand from the local system while often introducing new resources into that system. In essence, the ability of parts of the population to migrate or commute can be essential in order for the remaining population to develop productive resilient livelihoods in the location of origin.

Given the critical and often positive role migration and commuting play in the adaptive capacity of local populations, policies need to be developed that support this role while mitigating the negative consequences often associated with them.

Within countries critical areas where policies related to migration may need to be reviewed include:

1. The ability of migrants to access housing, health, education and other services for themselves and their families in destination locations; and
2. Policies affecting family members in home locations including those that affect access to banking and communications facilities.

Internationally, the critical role of migration in adaptation and livelihood resilience is likely to raise a wide variety of complicated policy issues. As the case of Yemen demonstrates, such policies are affected by political and other considerations that have little to do with climate change. Successfully adapting to the challenges likely to emerge in the context of climate change will, however, require policy environments that:

1. Enable local populations to obtain secure access to global labor markets. This will be particularly important for people from smaller countries,

such as Yemen and Bangladesh, that unlike, for example India, lack highly diversified internal economies.

2. Enable and encourage migrants to send remittances home and invest them in activities that support adaptation and the development of resilient livelihoods in home locations.

### **Remittances & International finance flows**

Policies that reduce the costs and increase the ease of sending remittances between destination and home location areas for migrants are of critical importance. Remittances through formal channels were estimated at around \$126 billion in 2004, well above the 78.6 billion of official development assistance and second only to the \$165 billion of foreign direct investment (World Bank 2005). These funds are often transferred at a very high cost to migrants - on average 12.5% (Cater 2005).

The above flows are, however, only part of the total. In addition to the formal banking and money transfer system, international remittances are often sent through informal channels such as the hawala network. This network and other forms of informal funds transfer have come under increased scrutiny internationally since 2001 because of their use by terrorist organizations. As Mohammed El-Qorchi, a senior economist at the IMF, points out, however, the system has tremendous advantages for migrants because “it is less expensive, swifter, more reliable, more convenient, and less bureaucratic than the formal financial sector” (El-Qorchi 2002).

The international situation has strong parallels in many national contexts. Rural banking and money transfer systems are often weak and migrants depend heavily on informal transfer mechanisms to send money back to home locations. In some situations, this may represent a critical constraint on the ability of local populations to access the financial resources required to diversify and build resilient livelihoods.

Overall, identification of mechanisms for reducing the cost and easing the remittance of funds from migrants to home locations is likely to be of increased policy importance as local communities struggle to adapt to climatic change.

### **Information Flow: Communications and Advanced Warning Systems**

Policies affecting communications and advanced warning have a major impact on the adaptive capacity and resilience of livelihoods. As discussed in several of the case examples, effective communications systems - i.e. access to reliable and low cost telecommunications services - were central factors

influencing the ability of local populations to diversify their income strategies. They enabled access to market information, supplies and customers in a manner that directly contributed to the ability of local populations to develop non-agricultural livelihood activities.

At the same time, the lack of advance warning represented a critical constraint on the ability of local populations to take proactive steps in advance of floods or droughts and thus reduce vulnerability.

Global experiences suggest that multi-function systems combining basic communications with advanced warning functions are often easier to maintain and far more likely to be operative when needed than special purpose systems. Dissemination of weather related warnings through phone networks, local radio, and TV systems is, in many cases, more effective than attempting to disseminate this information through dedicated warning systems. Enabling the spread of systems that are capable of meeting both daily communications needs and advanced warning requires, however, at least three policy issues to be addressed:

1. The development of protocols and systems for transmitting warnings over privately owned systems: The collection and transmittal of weather related information is, often a governmental function while communications systems such as cell phone networks tend to be private. As a result, protocols are required that enable the transmittal of advanced warning information through privately operated systems when required.
2. Supporting access to communications systems for vulnerable communities. Often those communities who are most vulnerable and would benefit the most from access to communications systems are the least able to afford them. Furthermore, communication networks often provide little coverage in vulnerable regions and devices are often poorly designed in relation to the needs of vulnerable communities. Cell phone coverage in rural Bihar, for example, is weak and handsets aren't designed to function in the rough wet environment of a typical flood zone. *Policies that enhance coverage, support the design of systems to meet the needs of vulnerable communities and reduce costs to affordable levels are of critical importance.*
3. Enabling real-time transmittal of data: where rapid onset disasters such as floods and storms are concerned, real-time transmittal of data is essential in order for advanced warning systems to function. In many parts of the world, however, data systems are controlled at a national-level and arrangements for real-time transmittal of data are not in place.

## ***National and Local Policy Issues***

At the national and local level, supporting the development of resilient livelihoods and adaptive capacity requires institutional frameworks that enable and, in fact, encourage changes in livelihood systems as both opportunities and stresses emerge. Some elements of this are much the same as in the trans-boundary policy arena discussed above. *The ability of people to migrate from affected regions and access labor markets within countries, the ability for them to send remittances home (and thus the importance of efficient and accessible banking systems) and efficient communication/early-warning systems, all are critical policy areas.* In addition to these, however, key policy areas include:

### **The establishment of community-based institutions.**

As both the Yemen and Gujarat cases demonstrate, the presence of effective community-based organizations is often a major factor enabling local action at a community rather than individual household level. In Yemen, the presence of a trusted local organization was a critical factor underlying the ability of local community members to bring remittance funds in and use them for activities (such as education and water management) that increased the adaptive capacity of the community as a whole. In Gujarat, the presence of local cooperatives enabled farmers to negotiate as a group within regional fodder markets and thus diversify out of agriculture during drought periods. In Nepal, local self-help groups provided the capital families used to develop diversified income sources in flood affected areas. Similar dynamics could be cited in many other locations. Overall, there are major synergies between the presence and strength of local community-based organizations and higher-level policy arenas related to migration, remittances and so on. The right to organize and the presence of legally recognized frameworks that, for example, enable organizations to open bank accounts are, as a result, a central piece in the adaptation puzzle.

### **Approaches to water management.**

In many cases, substantial tension exists between dominant water management paradigms and the factors that encourage adaptive capacity. Most approaches to water management, particularly ones involving river regulation, are designed to provide assured protection from extreme events such as floods. This assurance encourages settlement in flood prone areas and discourages investment in flood resilient housing, drainage and other activities that help local populations ‘live with floods.’ Similarly, in drought prone areas provision of assured water supplies encourages the development of intensive agricultural systems - and for that matter, domestic water use habits - that are poorly suited to the inherent variability of supply. From a scientific perspective,

climate change challenges the basic assumption of stationarity (i.e. the idea that water availability fluctuates around a stable and predictable mean value) that underlies engineering hydrology and the design of water control structures. Overall, as a result, the uncertainties associated with climatic change require approaches to water management at a national and regional scale that focus less on the reliability of supplies and more on the ability to adjust use patterns and protect key assets in response to variable and changing flows. Specific water related policy arenas that deserve attention include:

1. The role of informal water markets: As in the Yemen case, such informal water markets serve as a common and often vital adaptive mechanism for reallocating available supplies during times of scarcity. They aren't, however, particularly equitable. Instead of ignoring such institutions (the common approach in most countries), however, opportunities for working with them should be explored. Opportunities may exist for strategies that ensure a basic minimum supply to all people while allowing such markets to serve as the primary mechanism for delivering supplies above that minimum. This would be fundamentally different from most urban utility models.
2. Refuge, drainage and warning based strategies for flood protection: Rather than river regulation or fully integrated water management strategies, strategies emphasizing refuge, drainage and early warning could be far more effective and robust. The development of secure points of refuge requires far less precision with respect to flood flows, sediment loads and other hydrologic variables than a warning, drainage and refuge based strategy. It would, as a result, be far more resilient in the face of climatic change. Furthermore, unlike river regulation, the environmental and social consequences (no displacement) of refuge-based strategies are likely to be low.
3. Flood and drought adapted infrastructure design: Most water infrastructure is, in concert with the dominant management paradigms, designed to regulate flows. The development of forms of infrastructure that work with variability rather than attempting to control it is essential. Much could, for example, be learned from the *sayyal* spate irrigation systems of Yemen and the attempts by households to develop flood resilient housing in Uttar Pradesh and Bihar.
4. Adaptive water management and governance: Management approaches need to be designed in ways that contain specific mechanisms for adjustment as conditions change. The growing international literature on adaptive management can provide substantial guidance on this. In addition, policies need to support the development of governance frameworks that encourage and support adaptation. Such frameworks need to include access to information, the right to organize, explicit or

implicit mechanisms to balance power in society and enabling financial mechanisms (Moench, Dixit et al. 2003).

### **Credit and Banking Systems**

In addition to remittances, access to credit is often a significant factor constraining the ability of local populations to adapt. The ability to diversify income sources either locally or through migration requires investment. In many locations access to credit through formal banking systems is tied to specific activities. In rural India, for example, rural banks provide loans for agricultural activities (seeds, equipment, fertilizer, etc...) but it is much more difficult to obtain loans for the development of small businesses. Credit to meet expenses while migrating in search of a job (often the best investment a household could make) is not available.

In this context, households are forced to depend on informal systems in order to obtain the funds they require for diversification. Funding from such sources generally has very high interest rates and may be subject to other considerations such as caste or the specific social relationship between the borrower and the money-lender. As a result, access to credit and the cost of credit from informal sources represent key constraints on the ability of local populations to adapt to climatic variability and change.

### **Rural Economic Development Policies**

In many regions, economic development policies for rural areas focus heavily on agriculture. Diversification is, however, central to the ability of households to adapt to climatic variability and to develop resilient livelihoods. As a result, national level policies toward rural areas should support the development of diversified regional economic systems that include substantial non-farm components. Such policies would match well with trends toward economic integration that are occurring in many once rural and now increasingly peri-urban parts of the world.

### ***Programmatic - Disaster Mitigation and Development Programs***

At a programmatic level within the multilateral and bilateral organizations concerned with development and disaster relief, insights from the field and larger conceptual formulations related to adaptation have at least four interlinked policy implications:

1. Risk analysis and risk mitigation considerations need to become central features in the design and execution of development projects. In specific, development projects need to be designed in ways that manage

- but do not seek to eliminate climate related variability and risk exposure. From a systems dynamics perspective, the goal should be to reduce risk for vulnerable populations so that they are not exposed to catastrophic losses while not removing the incentives they face to diversify livelihood strategies and maintain their capacity to adapt.
2. Development strategies need to be designed in ways that are capable of taking strategic advantage of the windows of opportunity for change created by floods, droughts and extreme events. Development programs are often planned far in advance and are designed in ways that do not allow them to take advantage of the political and social opportunities for fundamental change that emerge following extreme events. As every water management expert knows, however, a good drought is the best opportunity to enact fundamental changes in water infrastructure, allocation and use systems. This is also the case with floods, storms and, in fact, any form of disruption to established livelihood systems. Approaches that are ‘proactively reactive,’ that is that focus on planning, the identification of critical changes and incremental implementation during ‘normal periods’ but are capable of moving quickly when the opportunity occurs are needed. From a conceptual perspective, the goal is to reduce the impact and speed the process of the ‘creative destruction’ and ‘reorganization’ phases of the systems dynamics cycle.
  3. Disaster relief and rehabilitation programs need to be structured in ways that reduce the exposure to future risks and encourage adaptation. Just as disaster risk reduction needs to be integrated within development programs, so development objectives and risk reduction need to be integrated into disaster response and reconstruction. In practical terms this implies that post-disaster recovery programs need to incorporate risk analysis and risk mitigation activities. In addition, mechanisms need to be developed for the groups and organizations working on disaster relief and reconstruction to work in close concert with those involved in longer-term development planning.
  4. Development and disaster relief and reconstruction activities need to seek out and be designed to leverage synergies between structural reforms and applied interventions and also between major resource flows. What this implies is best illustrated through few examples.
    - a. Structural reforms and Applied Interventions: Issues with migration and communications systems clearly illustrate the links between structural reforms and applied interventions. In the migration case, the effectiveness structural policy reforms around, for example, the issuing of work visas targeted toward individuals from vulnerable regions depends on applied

interventions such as the development of migrant support programs and effective banking systems for the return of remittances. In the communications case, structural agreements involving the development of international protocols for early warning through cell phone systems would depend for their effectiveness on applied interventions that ensured the functionality and affordability of cell phones in vulnerable communities.

- b. Synergies between major resource flows: As noted in the section on trans-boundary policy issues, foreign direct investments and remittances dwarf official development assistance at a global level and also within many developing countries. As a result, development programs need to be designed in ways that help to catalyze and leverage these larger flows into activities that support adaptation and livelihood resilience at the local level. This could be through, for example, support for the development of local organizations that have the potential to attract remittances into local activities or through targeted assistance for building the capacity of banking systems in vulnerable areas.

## CONCLUSIONS

Sustainability is as much about the flexibility and resilience of underlying systems as it is about the ability of groups to directly manage change. Successful adaptation to climatic variability and change will inevitably be a complex process. The process of adaptation will involve a combination of incremental activities that increase the resilience of existing systems and fundamental adjustments in livelihood systems.

Although this has not been directly emphasized in the preceding sections, governance considerations are central to the adaptive process. Many of the specific actions local populations will need to take to adapt - from migration-based strategies for income diversification to the creation of effective local organizations - have major political implications across the spectrum from local to national and international levels. How decisions regarding the right to migrate, the right to organize and the right of access to information are made will, as a result, have major implications for the ability of different groups to adapt successfully to floods, droughts, storms and the other consequences anticipated as a result of climatic change. Ensuring groups have an effective voice in the decisions that affect their future as climate change occurs is likely to have a major influence on specific outcomes, the degree to which those outcomes are perceived as legitimate and the tensions generated in what will inevitably be a difficult adjustment process.

Beyond governance, this paper highlights the increasingly obvious importance of integrating risk reduction into development, disaster relief and post-disaster reconstruction programs. It also highlights potentially less obvious issue areas. The fact that solutions to climate and water related problems often lie outside the water arena is one such issue areas as is the fact that frequent disruptions often (although not always) serve as catalysts for longer-term structural reorganization. Water problems can, in some cases, be ‘solved’ through income diversification. Droughts and floods are windows of opportunity for change rather than just disasters. Changes in perspective on these and other issue areas that recognize the key role of disruption in adaptation and seek solutions through lateral interventions are essential if society is to adapt successfully to climatic variability and change. Exposure to risk is central to the maintenance of adaptive capacity. Approaches that seek to eliminate risk are often, in the long run, counterproductive. As Walker and Holling *et al* argue, the implications of “SES dynamics for sustainability science include changing the focus from seeking optimal states and the determinants of maximum sustainable yield (the MSY paradigm) to resilience analysis, adaptive resource management, and adaptive governance.” (Walker, Holling et al. 2004).

In addition to the dynamic nature of change, key elements central to the identification and monitoring of progress toward successful adaptation are highlighted. In this paper we define successful adaptation in relation to the distribution of wealth, economic productivity and the maintenance of key environmental values. When regions are able to make fundamental changes in livelihood systems without major losses in relation to productivity and environmental values or substantial shifts in the standard of living and distribution of wealth away from vulnerable groups, the process of adaptation can be viewed as occurring successfully.

Finally it is important to emphasize the continued presence of numerous contradictions and challenges. Adaptation and short-term resilience may, in many instances (as the case of groundwater in India illustrates) be at the expense of resource sustainability. Furthermore, both the conceptual understanding of adaptive processes and observations regarding their practical application in flood and drought affected areas are in their infancy. Fundamental gaps in understanding regarding adaptive processes and systems dynamics remain. Research needs, as a result, to proceed hand in hand with initial steps to develop adaptive capacity and improve livelihood resilience across the range of scales at which interlinked social, economic and environmental systems interact.

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