

# Periurban water security in a context of urbanization and climate change: A review of concepts and relationships

## Vishal Narain

This paper seeks to contribute to developing a shared understanding of some of the core concepts related to water security in a periurban context. Though the relevant literature is cited at many places, this is not intended to be a literature review per se, but instead seeks to develop a shared framework to identify a set of common issues and questions that merit investigation. Towards the end of the paper, an analytic framework is proposed to guide the research. This is not meant to be a blueprint, but seeks to provide some common analytic framework to facilitate convergence across the research locations.

This is one of a series of Discussion Papers from the Peri Urban Project of SaciWATERS.

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## Periurban water security in a context of urbanization and climate change: A review of concepts and relationships

This paper seeks to contribute to developing a shared understanding of some of the core concepts related to water security in a periurban context. Though the relevant literature is cited at many places, this is not intended to be a literature review per se, but instead seeks to develop a shared framework to identify a set of common issues and questions that merit investigation. Towards the end of the paper, an analytic framework is proposed to guide the research. This is not meant to be a blueprint, but seeks to provide some common analytic framework to facilitate convergence across the research locations.

### 1. Conceptualizing periurban

The word 'periurban' is indeed a confusing term with many different conceptual connotations and several different mental images that may be attached to them. It is important to understand the meaning of the word 'periurban', as well as be familiar with some of the conceptual debates surrounding the term.

In this backdrop, we will review, in this section the various conceptual issues surrounding the use of the word 'periurban'. It is not possible to come to a consensus on place-based definitions of the term in terms of proximity to or distance of locations from the city. We argue that periurban is instead better understood in terms of its characteristics; a mix of agricultural and non-agricultural land uses, flows of goods, services and resources between villages and urban centers and a social profile that is very heterogeneous and in a state of flux. All these impact upon the local natural resource base, creating particular environmental and natural resource management problems that are often beyond the scope of urban or rural governments alone and require innovative ways of being addressed.

#### Is periurban a place?

There is indeed no single satisfactory definition of the word 'peri-urban' and different definitions are understood to apply in different circumstances (Mycoo, 2006; Brook and Purushothaman et al., 2003; Simon and McGregor et al., 2006). Nevertheless, the word 'periurban' is used in three main different ways, namely, as a place, a process or a concept (Narain and Nischal, 2007).

The notion of periurban as 'place' is perhaps the most widely understood conceptualization of the term. Shindhe (2006) notes that there are two main approaches to defining the periurban interface: spatially, as a transitional zone around a city and second as a zone of intense interactions, flows and linkages between urban and rural areas. When used in this sense, 'periurban' refers to rural fringe areas surrounding cities that bear the spillover effect of urban expansion. These areas provide the much needed land and water resources for urban expansion and serve as receptacles of urban wastes. Their residents are often portrayed as losers in urbanization and a case is made to involve them in urbanization processes (Narain, 2009a). Often they come into conflict with residents of the core city over the use and allocation of land and water resources (Janakarajan, 2009). Alternatively, these might be areas within the jurisdiction of the city or of urban authorities, but located at the periphery. Their residents often suffer from inadequate access to basic services and amenities and face exclusion from mainstream economic activity.

The terms used to describe such locations are periurban settlements, rural-urban fringe, urban outgrowth or hinterland. Since they bear the spillover of urban expansion, they are considered to be an extension of the main city. '... for many purposes, it is important to consider the periurban zone as an extension of the city rather than as an entirely separate area. Conversely, the periurban zone should also be considered as part of the adjacent rural area for purposes of a holistic approach to rural research and development since there are two-way influences and interactions (Simon and Mc Gregor et al., 2006: 9-10)'. Simon and McGregor et al. (2006) note that rapid urban population growth and expansion of the built-up area, technological change, global economic restructuring and the impact of externally driven macro-economic adjustment policies have combined to alter the interface between 'urban' and 'rural' quite profoundly in many places. Though the terms 'rural' and 'urban' are still used colloquially in traditional, mutually exclusive terms, and most people have clear mental conceptions of some ideal-type landscape corresponding to each, this simple dichotomy has long ceased to have much meaning in practice or for policy-making purposes in many parts of the global south.

In this context, 'periurban' serves as a term to denote the intermediary zone between the 'rural' and the 'urban'. This place-based definition is used to denote a geographical space where the rural meets the urban. This is echoed in terms that are used to connote periurban in other languages. The nearest equivalent to the term peri-urban in Dutch is halfstedig, meaning semi-urban; in German it is urban landlichen zonen (urban rural zones); and in Afrikaans it is buitestedelik (outer city or beyond the city). In East Asia the term often used is 'desakota' (city village) (Simon and McGregor et al., 2006; McGee, 1991).

## Towards process and concept-based definitions of periurban

However, there are several criticisms of place-based definitions of periurban. Iacuinta and Drescher (2000) question the tendency to define periurban in terms of geographical location of a place vis a vis urban centers, but rather underpin the importance of the underlying institutional contexts. This means that proximity to the towns in itself does not define periurban; rather it is the existence of both rural and urban characteristics, rural-urban linkages and the flows of goods and services between them.

This view is echoed by Bowyer-Bower (2006) who notes that a conceptual understanding of what constitutes 'periurban' - in particular, that it is where rural and urban land uses coexist, which may be in continuous or fragmented units in any one area - has greater validity as a basis for periurban studies than identifying 'periurban' purely as an urban periphery. This juxtaposition of the rural and urban land uses can geographically occur anywhere - in the core of the city, at its periphery or in a village.

In a similar vein, Brook and Purushothoman et al. (2003) caution against the tendency to treat periurban as a place, and argue that it is better understood as a process. As a process, periurban is used to describe a transition from rural to urban areas, as well as the accompanying flows of goods, services and resources between them. This relationship manifests itself in the two way flow of goods and services between rural areas and urban centres- flows of labour, natural resources and agricultural products (Narain and Nischal, 2007). Urban centres typically serve as markets for dairy and agricultural produce of the villages; villages provide labour to factories located in urban centres. This gives rise to different patterns and kinds of periurban interfaces.

An understanding and characterization of the periurban interface requires an appreciation of these linkages and flows of goods and services between urban and rural areas. These linkages tend to be mutually supportive and cyclical. They also perform important functions in terms of maintaining the social bonds between migrants and residents. For instance, migrant networks have been reported to perform important functions in facilitating migration and in channeling support to the wider home community (Tacoli, 2002). For these reasons, we sometimes use the word 'periurban' as a concept or analytic construct to study core - periphery relationships or as an interface of rural and urban activities and institutions. As an analytic construct, 'periurban' allows us to study rural-urban relationships and the flows of goods, services and resources between villages and urban centres. In this sense, we often speak of the 'periurban interface (PUI)'.

There is in general growing consensus in the periurban literature that the definition of periurban goes beyond the definition of a geographic location '...it appears that no single definition will fit all circumstances and situations unless couched in broad and functional terms, rather than attempting to set discrete spatial limits (Simon and McGregor et al., 2006: 10)'. A focus on conceptual distinctions is more appropriate for examining the continuum between the poles of urban and rural and understanding the dynamics of change as they affect particular parts of the periurban zone.

### Selecting peri urban locations for research

While selecting peri-urban research sites, it would perhaps be futile to demarcate a certain distance beyond the main city that could be called 'periurban'. Such a demarcation would be futile since the boundaries of cities keep geographically expanding; what is a village today may be reclassified as a town tomorrow and then as a city. Besides, definition of urban and rural will vary across the countries where the research sites are located. Thus, there may be little value in demarcating a 'periurban zone' with clear geographical boundaries. Instead, there is more merit in recognizing that the whole concept of periurban helps us to look at some grey areas, that are not amenable to an easy classification of what is 'rural' or 'urban'.

It is for this reason, perhaps that the word 'periurban' should be used not so much in its narrow, geographical sense, but more widely as an analytic construct to study the relationships between urban and rural activities, processes and institutions. Locations should be selected for study on account of the presence of certain characteristics, rather than their distance from the nearest towns or cities.

For instance, while studying water use and access in periurban contexts, one must be able to see how it has been impacted upon by the processes of urbanization. In other words, there must be some concrete evidence of flows of water between urban and rural locations, and how these flows have changed or been impacted upon by the processes of urbanization. These may take the form of, for instance, urban sewage being used for agriculture, water tankers moving from the village to provide water for the city or rural water supplies being appropriated for urban purposes. Also, these flows may not necessarily be physical, as marked by the physical flows of water from the village to the city or vice-versa, but they may also be in terms of the same location; that is, groundwater in a village being used by urban residents for farm-houses, a major 'urban' use of rural resources.

See also Narain (2009, b).

## 2. Characteristics of periurban areas: how do we know that we found 'periurban?'

As noted above, since periurban areas are involved in a process of transition, it is not possible to define them precisely spatially but some common features can be identified. Dangalle and Narman (2006) note some of these; periurban areas are situated within the metropolitan areas of a country but are often outside the formal urban jurisdictions; being a zone in transition, both agricultural and non-agricultural activities exist simultaneously, though the agricultural and rural characteristics are gradually replaced by urban landscapes and attendant changes in people's lifestyles. The continuous flow of people both from the urban core and the rural hinterland results in a complex social fabric. From the perspective of a development planner, the periurban zone offers a number of solutions to the industrial, commercial, residential and urban problems faced by a country; the locational advantages of these places make them the focus of modern economic activity such as export promotion zones and special economic zones. The urban periphery is considered to be an ideal location for a number of modern high-tech and high value industrial ventures (Dangalle and Narman, 2006).

Mycoo (2006) characterizes the PUI as a place that involves many processes that impact upon people; it is also a zone in which the process of social exclusion is experienced by many inhabitants of informal settlements who are poorly served by infrastructure and services; there is growing recognition that sustainability of cities and rural areas both is affected by dynamic and changing flows of commodities, capital, natural resources, people and pollution within the PUI. This zone is a place of competing interests, which lacks approaches that strike a balance required to ameliorate poverty, protect the environment, maximize the productivity of human and natural resources, to draw synergy from the urban and rural relationships. Peri-urban settlements reflect persistent neglect, conflict and competition.

### Environmental characteristics

The periurban interface is understood to have distinct environmental, social and institutional characteristics, though the intensity of these varies from one periurban context to another, and any attempt to generalize on these is fraught with severe limitations. Allen (2003) notes that from an environmental perspective, the peri-urban interface could be understood as a heterogeneous mosaic of natural ecosystems, productive or agro ecosystems, and urban ecosystems affected by the material and energy flows demanded by both urban and rural systems. In other words, it represents an interface of natural resources with both agricultural and urban productive activities. The relationship among these sub-systems is mutually constitutive and cyclical: each of these sub-systems conditions and is conditioned by the other two. The use of periurban environmental resources and ecological services might be driven by local pressures such as competition between residential and agricultural land uses, by sub-national and national policies like the promotion of dispersed industrialization, or by international pressures, such as falling prices of export crops, increasing the migration of impoverished farmers from rural areas to periurban locations in search of alternative livelihoods (Allen, 2006). These pressures result in a number of environmental problems and opportunities related to three main processes of environmental change; land use changes, changes in the use of renewable and non-renewable resources and changes in the generation of waste and the use of the absorptive capacity.

### Social characteristics

Socially, the periurban interface is interesting and dynamic as social groups are heterogeneous and in constant transition (Allen, 2003). Small farmers, informal settlers, industrial entrepreneurs and urban middle class commuters may all co-exist in the same territory, though with different and competing interests, practices and perceptions. The social heterogeneity in periurban locations results from the diversity of interests located there; real estate developers, miners, travel and transport service providers all inhabit the same spaces as farmers and livestock rearers. Iaquinta and Drescher (2000) note that socially, periurban areas are dynamic in nature, wherein social forms are constantly created, modified and discarded. They are areas of social compression or intensification where the density of social forms, types and meanings increases, fomenting conflict and resolution.

A unique characteristic of periurban settlements is that they often draw migrant labor that seeks employment in adjacent towns and cities, adding to the heterogeneity of the population. It is also common for relatives of periurban dwellers to migrate to the periurban settlements in search of better living conditions, amenities or jobs in adjoining towns. Thus, periurban areas serve as some kind of transit points for the inhabitants of more remote rural locations who wish to have a base for maintaining connectivity with the main city. At the same time, urban residents choose to live in periurban areas because they can manage cheaper accommodation than in the main city. Thus, periurban areas receive settlers and migrants from the main city as well as from the remoter rural areas.

One observation that is well established in the literature on the periurban interface is that rural out-migrants do not generally directly go to large cities (Iaquinta and Drescher, 2000). Instead, a series of moves is involved, called step migration, wherein rural migrants move first to villages or small towns and successively to more urban environments. In a study on patterns of maternal mobility in Kenya Molyneux and Mung'ala-Odera et al. (2002) found that most rural to urban migrants were familiar with urban environments before moving and having moved, continued to maintain strong ties.

This influx of migrant labor and residents in periurban settlements alters their social composition and has several implications for economic activities as well as for the demand for local resources. For instance, this may lead to a rise in the demand for rented accommodation (Narain, 2007). In particular, the influx of large numbers of migrants and short-term settlers can increase the demand for natural resources like water. Therefore, an important question to ask in this context is:

What is the social composition of our study locations? How has it changed in recent years? What implications does this have for the use of water resources? In what other ways has the changing social composition affected water management and use practices?

#### Institutional characteristics

Institutionally, periurban constitutes a range of activities that lie between strictly urban and rural jurisdictions. Periurban areas lie outside the legal jurisdiction of the cities and sometimes even outside the legal jurisdictions of municipal boundaries. At the same time, periurban dwellers are confronted with both urban and rural laws and institutions, breeding a situation of legal pluralism. This contributes further to the challenge of addressing periurban as a policy space. This creates the need for new and innovative institutional forms for bridging the rural-urban divide.

Intervening in peri-urban locations requires innovative ways of dealing with the situation arising from this fragmented nature of urban planning and rural development. One entry point might be to identify the various agencies engaged in the provision or the management of water, and trace the institutional vacuum or lacunae on account of which current water management problems arise. Multiple-stakeholders' meetings are considered to be a mechanism for dealing with this issue. In these meetings, stakeholders across rural and urban governments can be brought together, who otherwise would not interact, and the absence of whose interaction is an important factor behind periurban water management problems. A key question that thus follows is:

Which organizations are engaged in the provision of water in the study locations? Does this give rise to any institutional lacunae? How can they be addressed?

#### Land use change: periurban as a contested space

Land use change is perhaps the most essential characteristic of periurban settlements. Most cities grow by acquiring the lands of their peripheral areas. This is often a source of great tension and conflict between periurban residents on the one hand and governments and urban authorities on the other. The causes of conflict can be many, ranging from forced acquisitions to delayed compensations (Narain, 2009a; Ding, 2007; Ubink and Quan, 2000; Kombe, 2003).

The acquisition of agricultural lands often destroys the basis of rural livelihoods (Narain, 2009a). Even as agriculturists may be compensated through the process of land acquisition, often it is tenants and sharecroppers who suffer, as they receive no compensation. The landless lose out on their opportunities to earn a living on the lands of the land-owners. The discrepancy between the low prices that farmers receive for their land sold to municipal authorities and the high prices that these lands fetch when sold for private purposes can breed a sense of cynicism and social discontent among periurban dwellers. From Mexico City, it is known that peri-urban dwellers - surrounded by the growing city and still involved in animal husbandry - were resistant to selling their properties because they were afraid to lose their basis for a livelihood (Drescher 2005, oral communication). Similar stories are known to have been part of the land acquisition process in many other nations as well (Ding, 2007; Ubink and Quan, 2000; Kombe, 2003).

With the advent of urbanization processes, periurban areas grow in importance as they perform different functions for several people who put periurban land to several diverse and competing uses (Douglas, 2006). For the poor, they serve as places where it is easier to build shelters and to occupy land for agriculture; for industry, they serve as sources of materials essential for urban life such as water, bricks or clay; for the middle class, a place for houses in a rural setting with recreational facilities; for local governments, sites for discarding urban wastes; for conservationists, the site of valuable protected areas; for education and human well-being, the place of first urban contact with major areas of natural vegetation and biodiversity. For these reasons, a periurban location soon becomes a 'contested space (Douglas, 2006: 20)'.

The relevance of this characteristic of periurban areas for research is very straight-forward. In fact, the implications are two-fold: first, land acquisition directly affects the access of periurban residents to sources of water. That is, periurban residents may lose access to water sources located on those lands. At the same time, the presence of multiple claimants in the periurban locations increases the stress on water resources. Besides, urban and industrial actors may be able to employ expensive technologies for water extraction such as submersible pump-sets, that can not be afforded by the local population, who lose out in the race for appropriating water.

This understanding of periurban as contested spaces is essential for periurban research as it helps us understand how and why pressures grow on water in the selected areas. We need to understand the multiple claimants over the periurban lands and how land use change has occurred over a period of time. This changing land use pattern has clear implications for the use of water that then needs to be traced.

Thus, a relevant question to address is;

Who are the claimants over water in peri-urban locations? How have these changed? What implications does this have for the access of periurban residents to water? What new challenges does this create for water management?

### Periurban livelihoods

Periurban livelihoods are complex, and constructed across both rural and urban domains. It is important to note two essential characteristics of periurban livelihoods; first, there is a role both of rural and urban assets and opportunities and second, these livelihoods are sustained largely through links with cities and adjacent urban centres, that are sustained, in turn, through a wide diversity in the means of transportation.

A distinguishing characteristic of the periurban interface is the role of both rural and urban resources in maintaining household security (Baker and Wallevik, 2003). Periurban households draw their income both from agricultural activities as well as casual or regular employment in the neighboring cities. Further, inequalities tend to exist widely as the elite are able to pre-empt both urban and rural resources for accumulation while the not-so-well off negotiate and struggle for survival (Tacoli, 2003). This observation provides a very good entry point for analyses of vulnerability and the identification of poorer households; wide inequalities can exist in periurban areas on account of the varying capabilities of periurban residents to benefit from access to urban and rural assets and livelihood opportunities.

In a study in northwestern Tanzania, Baker (2006) found that the more secure rural and urban households adopted a range of diversification strategies involving risk spreading by having one foot based in rural activities and one based in urban activities. For many village households, while agriculture was the mainstay, non-farm and off-farm economic activities in addition to agricultural land were central components in the household security and accumulation strategies. Likewise, for urban dwellers, access to agricultural land, in addition to urban employment, was an important component of livelihood diversification strategies. Through processes of risk aversion, income diversification and multi-activity, straddler households were successful accumulators who generated wealth which was used inter alia for acquiring/buying more land, acquiring more assets or improving the value of existing assets.

Similarly, village studies in Southeast Asia during the 1980s showed that there was increasing diversification away from agriculture; new non-farming activities, sustained or created by ongoing processes of development and urbanization formed the core of diversification strategies (Rigg, 2006); for rich households, on-farm activities constituted a strategy for accumulation; for poor households, a strategy for survival and for middle households, a strategy for consolidation.

Drawing on a study in Botswana, Kruger (2006) noted that a considerable number of migrant households, who had moved to the city, continued to engage in farming activities even when working in the formal or informal urban employment sector on a more or less regular basis; rural attitudes tended to be preserved in the cities and mental links were maintained with the rural 'homes'; even the urban settlers depended upon their rural asset bases as sources of income, giving rise to a phenomenon of what Kruger calls 'the ruralization of cities'.

It can indeed be possible to find great variation in the livelihoods profile within a village in a periurban location. The livelihood story of one household can be very different from that of its' neighbours in terms of the diversity of the livelihoods portfolio. There can even be much greater variation at the household level itself. A household can derive its income from a mix of agriculture, petty trade, urban employment, real estate, transport and travel services. This is worded very nicely by Rigg (2006) who says '.... in a sense, and paradoxically, the household is defined by dissonance (Rigg, 2006: 79)'.

This has both operational and methodological implications for periurban research. While trying to identify the vulnerable households in terms of their poverty and access to resources or livelihoods, it is important to look at the wide range of activities that households are engaged in across the village and the city. Households with a good asset base in the cities and a more diverse livelihoods portfolio will be less vulnerable to losses of income that may accrue as a result of shocks and stresses affecting agriculture. Urban assets of periurban households can serve as a buffer against shocks or stresses - including those related to the availability of water - that affect agriculture. Likewise, households with a larger dependence on urban assets may suffer shocks and stresses that affect urban activities. In assessing vulnerability, therefore, we have to look at the relative role of both rural and urban activities and livelihood opportunities in the livelihood mix of different households.

Multiple income generation and the involvement of children in economic activities are largely strategies of poor periurban women who do not have access to sufficient cash to guarantee access to the basic needs of life (Brook and Purushothaman et al., 2003). In some studies on livelihoods in the periurban interface, migration is shown to provide a socially acceptable alternative for young women who try to escape from familial and community control (Tacoli, 2002). Remittances are an essential aspect of periurban livelihood strategies. Sending remittances is perceived as a moral obligation, as well as a way to maintain claims on assets in home areas. Once again, periurban households with one or more members residing in urban areas and sending remittances may be better able to absorb the shocks and stresses associated with an unpredictable and uncertain water supply. In general, the urban linkages of periurban residents in terms of their assets, livelihoods opportunities or remittances from family members have to be factored into the vulnerability analyses.

### So, a relevant question to ask is

What is the role and relative contribution of agricultural and non-agricultural assets and livelihoods in the livelihoods profile of the households under study? How does this influence their vulnerability to an uncertain water supply?

The emergence of the periurban interface itself creates important changes in livelihood opportunities and options, though the ability of periurban residents to benefit from these depends on several factors. In the Hubli-Dharwad region in India, for instance, the creation of urban markets combined with the availability of irrigation created an opportunity for farmers to raise cash crops (Brook and Purushothoman et al., 2003). As agricultural workers commuted to the cities for work, there occurred a shift to the less labour-intensive crops such as mango cultivation (Halkatti and Purushothoman et al., 2003). Dairying turned out to be an important livelihood for periurban landless near the city; buffalo numbers increased over the previous decade, particularly in the landless households. This could be contrasted with observations in periurban Gurgaon where the gradual acquisition of agricultural lands has altered the status of farmers from commercial to subsistence farmers or tenants (Narain, 2009a). At the same time, as households diversify, and spend more time in non-farm employment, they may switch to less labor-intensive techniques of irrigation – such as sprinklers – as seen in periurban Gurgaon (Narain, 2010). Therefore, the relevant question to ask is:

How does the growth of cities affect agricultural production –in terms of the crops, the scale of production or the technologies in use? What implications does this have for the use of water resources?

Sewage-irrigated agriculture is a common feature of periurban agriculture, as urban sewage provides a cheap source of nutrients and removes the need for costly application of fertilizers. It may also remove the need for costly pumping and water extraction. However, the use of untreated sewage is known to have long-term health effects.

Kundu and Konar et al. (2001), for instance, describe the process of the emergence of the periurban area adjacent to Kolkata. This region was found to practice three productive activities namely pisciculture, vegetable and paddy culture, utilizing the city's sewage and garbage. The periurban agriculture in the rural fringe area of the city was traditionally confined to the production of rice, wheat, potato and vegetables like in other rural areas of West Bengal. Subsequently, construction of new roads and railway tracks opened up the possibilities of transportation of the area's produce to the urban market.

Likewise, in a study in the peri-urban regions of Hanoi, Vietnam, van den Berg and van Wijk et al. (2003) notice a series of changes in livelihoods. The production of pork, vegetables, and fish increased, while that of paddy underwent a decline; farmers faced a number of problems from the loss of rights to agricultural land, water contamination by city wastes and seasonal flooding. Urban and industrial effluents were used by farmers and fish breeders as a free substitute for chemical fertilizers and fish food from factories. These dimensions of change in agricultural practices that take shape as a result of urbanization and the linkages of villages with urban centres present investigative issues in periurban research, moreso of the implications for the use of water resources.

Further, the process of “periurbanisation” distributes risks and opportunities unequally. Farmers who have their agricultural holdings geographically dispersed may suffer less from the risks of land acquisition than do farmers whose lands are geographically concentrated. In the above mentioned study in periurban Gurgaon, farmers were found to be able to gain from diversity in sources of irrigation depending upon the location of the fields (Narain, 2009a). Farmers with lands lying adjacent to sewerage canals were able to gain from sewerage irrigation, while others had to stay content with other sources, predominantly tubewells. An understanding of these observations once again is useful as a clue in vulnerability analyses. We should try to identify the various factors that shape the vulnerability of households to an unstable water supply. For instance, as noted above, land-owners with their agricultural lands geographically scattered will have access to more diverse sources of irrigation and will be less vulnerable to a loss of sources of water supply that result when particular tracts of their agricultural lands are acquired.



Besides, in many periurban locations, periurban residents invest the proceeds from land sales in fresh land acquisition in other villages, and even in other districts. As in the case of urban assets, these assets serve as cushion and can help them absorb the impact of certain local shocks and stressors.

### Changing locus of control over natural resources

Often the locus of control over village resources moves to urban dwellers, who take part in auctions of village natural resources, as was found in research in the Faridabad and Gurgaon districts of Haryana (Narain and Nischal, 2007; Narain, 2010). Periurban livelihoods dependent on natural resources face a particular threat as common property resources on which people depend for their sources of fuelwood, fodder and water get diverted to other purposes.

The acquisition of common lands for the construction of brick kilns may adversely affect the access of the landless to sources of energy, who procure fuelwood from the common lands (Narain and Nischal, 2007). Likewise, when village ponds are filled and acquired for urban and residential purposes, people who depend on them for their livelihoods – such as the potters who obtain clay for them through desilting - are adversely affected. How the changing control over or acquisition of village common property resources affects local access to water, which groups of people are affected most by it and what strategies they adopt to adapt to this changing access, are important issues for investigation when studying changing water use in periurban contexts. Thus, the broader question that needs to be addressed is :

How does control over local natural resources change with the processes of urbanization? How does this affect local livelihoods? Which groups of periurban residents are the most vulnerable?

While selecting research sites, one needs to look for the kinds of characteristics described above. These characteristics may exist within the administrative jurisdiction of a city, in its vicinity, or very far. They are more likely to be found in places where substantive land use change has already occurred from agriculture into other non-agricultural uses; where much more is occurring and is on the anvil. Claimants over land use are multiplying and competition increasing. The social mix is heterogeneous and rapidly changing; a wide variety of agriculture and non-agriculture based livelihoods exist. A changing land use pattern is a basic driver of transition in periurban locations.

Visually, it may possible to recognize periurban by what is called a 'periurbanscape' (Narain, 2010) - a sight where agricultural fields, brick kilns, farm-houses of the urban elite, village ponds and grazing lands, modern residential buildings and skyscrapers all co-exist. When we see such a place- as we often do when we drive a highway after leaving a large city – we know that we have found periurban. Further, it is important to recognize that the above characteristics have implications for vulnerability studies in periurban contexts. This helps to position vulnerability studies in periurban settings against other vulnerability studies – most of which are either in purely 'rural' contexts, or build around the vulnerability or resilience of larger cities to the effects of climate change.

### 3. Vulnerability, capacity and resilience

Vulnerability, capacity and resilience – these three concepts have been particularly strong and structuring within the disaster risk reduction literature where both the concepts of vulnerability and capacity emerged in the 1970s and 1980s (Gaillard, 2010). Since then they have sustained discourses on Sustainable Development, Climate change mitigation and adaptation. The use of these words has gained much prominence in current discourses on climate change. This section strives to develop an understanding of these terms and also examine their relevance for periurban research in a context of climate change.

#### Vulnerability

The term 'vulnerability' was in the disaster literature as early as the 1980s (Gaillard, 2010). In the 1980s it appeared in the climate change and development literatures as well.

This concept is used to describe people and organizations that are negatively affected, directly or indirectly, by a single process or event (O' Brien and Quinlan et al., 2009). In general, this concept is used to draw attention to the specific contextual factors that influence exposure and the capacity to respond to change in order to explain how and why some groups and individuals experience negative outbreaks from shocks and stressors (Leichenko and O'Brien, 2002). It is thus to be seen as a concept that captures the changing nature of risks as well as the variable capacity to cope with both risk and change (Kirby, 2006).

The concept originated in research communities examining risks and hazards, climate impacts and resilience (Shirbinen and Schiller et al., 2007); it emerged from the recognition that a focus on perturbations alone (environmental, socioeconomic, technological) was insufficient for understanding the responses of and impacts on systems (social groups, ecosystems, places) exposed to such perturbations. A clearer understanding of coping strategies can help get a better understanding of who and what are at risk from what and how specific stresses and perturbations evolve into risks and impacts.

In the social sciences, therefore, vulnerability is typically defined in terms of three elements, namely, 1) system exposure to crises, stresses and shocks 2) inadequate system capacity to cope, and 3) the consequences and attendant risks of slow or poor systems recovery.

The most vulnerable groups, individuals or places thus tend to be those that experience the most exposure to perturbations or stresses, are the most sensitive to perturbations or stresses (i.e. the most likely to suffer from exposure) and have the weakest capacity to respond and ability to recover. Vulnerability needs to be understood therefore as the susceptibility to harm, rather than a measure of harm (Nelson and Kokic et. al., 2010). Vulnerabilities often depend on structural constraints which are exogenous to the community, such as unequal distribution of wealth and resources within the society, market forces, political system and governance. Vulnerability is a good proxy for marginalization and exclusion; vulnerability in facing natural hazards reflects people's marginalization within society. For instance, disaster affected people are marginalized geographically because they live in hazardous places such as informal settlements; socially, because they are members of minority groups; economically because they are poor, and politically because their voice is disregarded. Vulnerability may also result from inadequate social protection and limited solidarity networks.

Within both research and practitioner communities, vulnerability reduction is increasingly recognized as necessary for improving human well-being and human security in the face of multiple shocks (O'Brien and Quinlan et al., 2009). Human security describes a condition when and where individuals and communities have the options necessary to end, mitigate or adapt to risks to their human, environmental and social rights (GECHS, 1999). Reducing the vulnerability of the most vulnerable households involved in agriculture and elsewhere in the developing world requires complementary measures to safeguard natural resources to promote market access and to augment human capital. Effective governance of natural resources such as forests, land cover and water is needed because they provide a safety net for vulnerable groups (Paavola, 2008).

In recent years, the concept of vulnerability has gained prominence within the climate change discourse, wherein it has come to describe the risks posed to rural communities by climate variability and change. The vulnerability of human-environment system to climate risks is widely agreed to depend on their relative exposure to climate variability and change, their sensitivity to exposure and their capacity to adapt. It therefore highlights the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards. It stresses the condition of a society that makes it possible for a hazard to become a disaster (Gaillard, 2010).

There are two conceptual issues surrounding vulnerability that are of particular relevance for our research. First, the key to understanding vulnerability is to identify where and how different stressors interact; thereby indicating that vulnerability can be used to draw attention to the effects of multiple stressors on people's well-being and livelihoods (de Waal, 2006). Processes such as epidemics or environmental changes are not occurring in isolation of one another, or in isolation of other stresses (Leichenko and O'Brien, 2002). This dimension of vulnerability analyses is very important because this concept can be used to study the interaction of two stressors – namely, urbanization and climate change – for the water security of periurban residents. That is, an examination of how these pressures interact helps us conceptualize water security as being shaped by the dual processes of climate change and urbanization. The longer-term theoretical contribution that can be made through such research is in terms of showing how multiple stressors interact, how they shape water security, how users can respond or adapt to them. Water users in South Asia do face water related vulnerability from climate change; but climate change is only one of the factors, that operates along with other stressors – in the case of periurban residents, that of urbanization.

A second point of relevance is in how vulnerability is viewed conceptually vis a vis its treatment in current discourses on climate change. It is perhaps better seen as a chronic phenomenon, as noted by Mustafa and Ahmed et al. (2008), rather than one emerging in response to extreme events or disasters. Water researchers in South Asia need no reminding that uncertainty and variability in water supply is a day to day reality for water users, and not just a situation associated with extreme events.

### Adaptation

The IPCC (2007) defined Climate Change Adaptation (CCA) as an adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderate harm or exploit benefit opportunities. CCA strategies aim to reduce vulnerability to expected impacts of Climate Change, even though climate change may only be one of the factors shaping vulnerability (Mercer, 2010).

Indigenous and non-indigenous communities have been adapting for centuries to climatic trends and extremes; while some have experienced losses, others have adequately recovered through building back better or building back safer; there is thus a vast wealth of knowledge in relation to adapting to change and dealing with disaster. One has to look at how periurban water users adapt to the changing water availability as a result of urbanization and climate variability. What mix of technologies or institutions do they employ? What insights does this give into adaptation strategies in general?

### Coping capacity and resilience

Coping capacity can be defined as a combination of all strengths and resources available within a community or organization that can reduce the level of risk or the effects of a disaster (UNISDR, 2002). The concept of capacity emerged from development practitioners in the late 1980s; it reflects the increased recognition of people's ability to face climate related and other natural hazards. The concept essentially emphasizes the notion of human agency; people are not passive victims of negative events that affect them, but are endowed with skills and resources that enable them to deal with or tide over negative events that affect their lives.

Capacities are often rooted in resources which are endogenous to the communities and rely on traditional knowledge, indigenous skills and technologies and solidarity networks. The ways in which capacities are mobilized in times of crises reflect coping strategies. The concepts of capacity and resilience further reflect the emergence of the vulnerability paradigm; peoples' capacities emphasize that those affected by disasters should not be considered as helpless victims whose risk perception should be changed from the outside; development policy should use people's capacities to help the people themselves to rebuild and to reduce future disaster risk.

### Hazard and risk

Hazard is understood as a potentially damaging physical event, phenomenon and/or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (UNISDR, 2002). The term risk encompasses the probability and the amount of harmful consequences or expected losses resulting from interactions between natural or human induced hazards and vulnerable conditions (UNISDR, 2002). The relevance of hazards and risks will vary across research locations, depending on the likely impacts of extreme events like floods, droughts, glacial outbursts and others.

## 4. Understanding Institutions

Though in a layman's language the terms institutions and organizations are used interchangeably, in academic parlance, they have different meanings, and a shared understanding of how one would use these terms is essential.

The term institution is widely dealt with in the social sciences, with subtle differences in interpretation. In the New Institutional Economics, for instance, institutions are defined as rules of the game in society that structure human interaction (North, 1990); they could be formal as well as informal. Institutions include law, property rights, social relationships (social capital), values and belief systems. From a new institutional economics perspective, institutions are seen as a way of reducing transaction costs inherent in human exchange. Transaction costs are the costs of information, contracting and enforcement; in other words, they are the costs of dealing with the market. By providing a structure and predictability to human interaction of a repeated nature, institutions are seen to reduce the transaction costs inherent in human exchange. Likewise, sociological and anthropological approaches to institutions focus on the regularization of practices and codes of conduct. Giddens (1984) defines institutions as regularized practices performed over time. Institutions are 'Regularized patterns of behavior between individuals and groups in society (Mearns 1995; Leach, Mearns and Scoones 1999)'.

This understanding of institutions may be applied in specific contexts to denote, or to refer to the principles of social organization. For instance, when this understanding of institutions is applied in the context of natural resources, the reference is to conventions and practices that structure human interaction with nature. Agrawal (1999) defines institutions as sets of formal and informal rules and norms that shape interaction of humans with each other and with nature- without them social interaction would not be possible. Institutional arrangements could thus be defined as rules and conventions, which establish people's relationships to resources, translating interests into claims and claims into property rights.

The term institutions should be distinguished from organizations- that could be defined as bodies of individuals with a specified common objective. Organizations could be political organizations (political parties, governments, ministries), economic organizations (federations of industry), social organizations (NGOs, self-help groups) or religious organizations (church, religious trusts) (North 1990, 1986, 2006).

While referring to G-8 as an organization, we refer to it as a body with a certain membership and objective(s). While referring to it as an institution, we refer to rules and regulations surrounding its membership and practices of decision-making. The High Court and Supreme Court are organizations, while the judiciary is an institution.

It might be difficult to separate an organization from the institutions that govern its working, and at times the distinction can get very thin. Uphoff (1993) argues that institutions are complexes of norms and behaviors that persist over time by serving collectively valued purposes, while organizations, whether institutions or not, are structures of recognized and accepted roles. Institutionalization is a process and organizations become institutional over time to the extent that they enjoy status and legitimacy and for having met their normative experiences. The relationship between institutions and organizations is multi-faceted. All organizations are governed by institutions- systems of rules, regulations and codes of conduct. Organizations can also alter the institutional framework under which they function, and new institutional economists like North (1990) use this phenomenon to explain how economies grow differently.

#### Relevance to peri-urban research

For the purposes of studying water access in peri-urban contexts, the conceptual distinction between the terms institutions and organizations is useful. While looking at the role of institutions in adapting to water scarcity, we look at the role of such factors as social relationships, property rights and systems of land tenure and forms of social capital. This would include both formal institutions (explicit, written, often having the sanction of the state) or informal (unwritten, implied, tacit, mutually agreed and accepted) institutions. Alternatively, this could be articulated as the distinction between statutory and non-statutory institutions. This should be distinguished from the role of organizations such as village Panchayats, resource management committees, water user groups as well as government departments and agencies like urban planning authorities. Both – institutions and organizations - play a role in shaping access to water, and researchers tend to be interested in studying both, as well as the relationships between them.

#### Institutional or legal pluralism

It is interesting to note that more than one set of rules, regulations and institutions pertaining to a field of activity may exist at the same time. In the legal anthropological literature, this is referred to as legal pluralism. Legal (or institutional) pluralism is a term used to denote the co-existence of more than one legal or institutional system with regard to the same set of activities. For instance, state law may co-exist with customary law and practices, social relationships and local systems of property rights and tenurial systems. Legal or institutional pluralism provides an analytical framework for the analysis of the interface of statutory and non-statutory institutions. This concept of legal pluralism may be used to understand the interface of urban and rural institutions or the interface of statutory and non-statutory institutions in shaping access to natural resources. Water rights may often be defined by state law, but realized through other normative systems, such as systems of social organization or forms of social capital. In a periurban context, one may notice situations of legal pluralism while observing the interface of institutions embedded in the rural fabric with more 'urban' forms of institutions, that the periurban interface brings in its wake.

#### Social capital

Social capital is a term widely used in the development literature to denote the quality of an individuals' social relationships, networks and ties. The concept is explored in disciplines as diverse as criminology, political science and international development (Mackenzie and Harpham, 2006). It is widely used in studies of natural resource management and sustainable livelihoods to show how individuals mobilize their networks, ties and social relationships to secure access to livelihoods. Essentially, the term attempts to describe features of populations such as levels of civic participation, social networks and trust (Mackenzie and Harpham, 2006); such forces shape the quality and quantity of social interactions and the social institutions that underpin society. An individual's social relationships allow differential access to resources; these relationships define social capital (Bourdieu, 1986).

Mackenzie and Harpham (2006) note that social capital is indeed a complex concept; it is difficult to consider it a single continuous variable; areas and people can not be simply categorized as having 'high' or 'low' social capital. Some scholars see social capital as an ecological phenomenon embedded between individuals, groups, and between groups and abstract bodies such as the state. Putnam (1993) defines five characteristics of social capital:

1. Community networks, voluntary, state, personal networks and density
2. Civic engagement, participation and use of civic networks
3. Local civic identity, sense of belonging, solidarity and equality with local community members
4. Reciprocity and norms of cooperation, a sense of obligation to help others and confidence in return of assistance and
5. Trust in the community

### Relevance to peri-urban research

The concept of social capital is relevant to natural resource management studies in periurban contexts for three reasons: first, social capital plays an important role in shaping access to natural resources. Resource users mobilize forms of social capital – their networks and social relationships - to improve their access to natural resources. Social capital can be seen as an essential component of the institutions through which individuals access natural resources. Second – and stemming from the above - social capital is considered important in discourses of climate change. It strengthens the resilience of communities; communities are seen to mobilize social capital in adapting to climate change. Third, and paradoxically, periurban areas are often characterized by erosion of social capital. This can be on account of several factors: migration to cities can erode social capital; collective activities that provide social glue may gradually decline in importance with urbanization and occupational diversification characteristic of peri-urban areas. Common property resources such as land and village ponds that bind people together are often acquired for urban purposes weakening the ties that bring the resource users together.

Mackenzie (2008) notes that the types of urbanization that are a consequence of globalization may be expected to decrease social capital; migration can break the bonds between people, that are the substrate of social capital; rapid unplanned urbanization undermines the development of social capital, just as migration to cities – very common in peri-urban areas - can undermine it as well. Rapid urbanization may have an impact on the level of structural social capital in an area; in areas where migration is prevalent there are fewer relationships networks, associations and institutions that link people and groups together. Mackenzie further notes that if, for instance, governments are to take seriously the need to avoid the health impacts of rapid urbanization, they could start by considering how to promote the maintenance of existing social capital for migrants, how to develop bridging social capital between migrant groups and how to produce urban areas with structures that allow new city migrants to be involved in local governance.

### Land tenure security

An essential aspect of institutions in periurban contexts is that of land tenure. Land tenure is the relationship, whether legally or customarily defined, among people, as individuals or groups, with respect to land and associated natural resources, including water, trees, minerals and wildlife (Clover and Eriksen, 2008). It can be defined as the terms and conditions on which land is held, used and transacted, determining who can use land resources for how long and under what conditions.

Land tenure security is understood to comprise a full set of use and transfer rights vested in communities, groups, households or individuals - whether formal or informal. Secure tenure implies being able to enforce those rights against the claims of others as well as having the ownership of the land over a sufficiently long period of time to benefit from the labour and capital invested in it. Tenure security is widely acknowledged as critical for people's rights and livelihoods, for gaining access to credit, for intensifying agricultural production and as a powerful incentive for sustainable land management practices and interventions. Access to resources and particularly land is mediated by institutions such as property rights and affects the vulnerability of households; insecurity of land tenure can fail to create incentives to invest in productivity.

Access to land is recognized as being fundamental to most family asset bases and to social sustainability in terms of food security as capital and buffer against external shocks and as a safety net (Quan, 2005). In most South Asian societies, rights to land are the basis for social relationships and cultural values and a source of prestige, power and political status. The way that land tenure arrangements promote or inhibit on-farm and off-farm diversification as well as political and social rights to land has important implications for human security and sustainability. Security of tenure emerges as crucial for sustainability.

An understanding of land tenure arrangements is very essential in periurban research for the following reasons. First, land tenure arrangements define people's access to land, which, as we noted above, is constantly changing in periurban settlements. This can be a reason for great conflict and discontent. Since land acquisition is a constant reality in periurban areas, the (in) security of land tenure is a very basic issue in periurban settlements. Second, in much of South Asia, access to water is tied to access to land. Thus, insecurity of land tenure translates into water insecurity as well; all it takes for a farmer's tubewell to go is a notice that the land on which it is located is being acquired. Therefore, to understand water insecurity in periurban settlements we need an understanding of the land tenure arrangements and the conditions under which land is owned, or ownership transferred. In India, for instance, most of this is rooted in the Land Acquisition Act of 1894. There are likely similar provisions for other countries in South Asia as well. Third, in periurban settlements, land tenure arrangements such as sharecropping or tenancy play an important role in maintaining the relationship of periurban residents with their home assets in rural areas, even as they migrate to cities. That is, they provide a mechanism for periurban residents to engage both with urban as well as with rural livelihoods. Even as they migrate to cities, they maintain a hold over their rural assets by giving them out on contract. Urbanization processes impact upon the nature of land tenure arrangements as well (Narain, 2010).

## 5. Water Security

Related closely to the concept of the security of land tenure is the concept of water security; in academic terms, water security can be conceptualized on lines similar to the security of land tenure. The dictionary meaning of the words 'secure' and 'security', however, capture much better what we are trying to investigate in the current project. As per the Concise Oxford Dictionary, 'secure' refers to 'safe, reliable, stable, fixed'. 'Security', then, is a 'secure condition or feeling'. Thus, water (in)security could be conceptualized as a condition of uncertainty in the availability of water. In periurban contexts, water insecurity could be seen as being shaped by the parallel processes of climate change and urbanization.

## 6. Technology

For the purposes of this project, we will follow a simple dictionary meaning of technology which, as per the Concise Oxford Dictionary is 'knowledge or use of mechanical arts and sciences; these subjects collectively.' Essentially, we will use the term to denote physical artifacts through which water users access water, such as treadle pumps, tubewells, dugwells, submersible pump-sets, pipe outlets, pipes and hoses, sprinklers and drip irrigation sets, as well as traditional spouts, step-wells and pulleys. These artifacts are seen as the embodiment of certain types of knowledge, that could be embedded in traditional knowledge systems, beliefs and practices as well as the 'modern', scientific, western engineering dominated technologies. These technologies are not socially neutral, but are seen as having certain social or organizational characteristics, in terms of their operational implications, affordability or social effects. Thus, the questions that need to be addressed in this regard are:

What technologies do different users employ to access water? Does urbanization impact the use of certain technologies? When urbanization processes affect water availability, do users adopt alternative technologies? What are the consequences of this for periurban residents – both those who use the resource, as well as those who are left out?

In general, while studying adaptation to water scarcity or insecurity, the questions that we should try to address are:

What mix of technologies and institutions do water users employ to adapt to water scarcity/insecurity? Can we think of some socio-technical regimes – comprising a mix of technologies and their concomitant institutional characteristics through which access to water is shaped?

## 7. Ecological foot-print

Cities, like other assemblies of organisms, have a definable metabolism, consisting of the flow of resources and products through the urban system for the benefit of urban populations; the metabolism of most cities is essentially linear, with resources being pumped through the urban system without much concern about their origins or the destination of wastes, resulting in the discharge of vast amounts of waste products incompatible with natural systems (Girardet 2004). Ecological foot-prints give us some answers to the questions or estimates regarding a city's resource metabolism.

Ecological foot-print analysis is an accounting tool that enables us to estimate the resource consumption and waste assimilation requirement of a definite human population or economy in terms of a corresponding productive land area (Wackernagel and Rees, 2004). The total eco-system area that is essential to the continued existence of the city is considered to be its de facto ecological foot-print. It is proportional to both population and per capita consumption.

For modern industrial cities the area involved is orders of magnitude larger than the area physically occupied by the city; it represents the corresponding population's appropriated carrying capacity. For urbanization, food, forest products and fossil fuel use, for instance, it is estimated that the Dutch use the ecological functions of a land area over fifteen times larger than their country (Wackernagel and Rees, 2004).

By measuring the overall supply of and human demand on regenerative capacity the ecological foot-print serves thus as an ideal tool for tracking progress, setting targets and driving policies for sustainability; the concept has been important in encouraging urban planners and environmental managers to look beyond the traditional scales of planning and environmental management to consider the regional and international environmental impacts of a city's activities (McManus and Haughton 2006).

The concept of ecological foot-print helps us analyse the rural-urban linkages that facilitate the expansion of cities. Problems of environmental and natural resource management in periurban areas are the result of the ecological foot-print of large cities spilling over into periurban areas. The concept thus helps us to frame the issue and understand the periurban locations as receptacles of the spill-over of the ecological foot-print of growing cities. In a sense, an overarching question for research is:

What are the different ways in which the ecological foot-print of modern cities is borne by periurban locations? What are the implications of this for land and water resources? How do these processes, along with climate change, shape the water security of periurban residents, and how do users adapt to them? who are the vulnerable groups and how can their vulnerability be reduced ?

## 8. Towards a conceptual framework

After a review of basic concepts and terms, a conceptual framework for our research linking water security, climate change and urbanization can be presented as follows:

In periurban contexts, water security is shaped by the twin processes of climate change and urbanization. These processes act as multiple stressors and create an uncertain water supply for peri-urban residents. Urbanization processes affect water security through changes in land use patterns which increase pressures on water resources as well as through the links between land tenure and water security. Periurban residents adapt to this situation using a mix of technologies and institutions. They, however, differ in their adaptive capacity as well as resilience, which is shaped in large part by their ability to mobilize social relationships, access to urban assets, linkages with the urban centres and access to technologies. As a result, periurban residents exhibit varying degrees of vulnerability. A key agenda for research is to identify who the most vulnerable groups or individuals are and how their vulnerabilities can be reduced.

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## Water Security in Peri Urban South Asia: Adapting to Climate Change and Urbanization

Working primarily on water security issues in Peri-Urban South Asia, across India, Bangladesh and Nepal, the project's main concerns are the rapidly changing peri-urban landscapes due to urbanisation and implications for water security in specific locations in the larger context of climate change. As an action research project, working across four locations in South Asia, it will serve as a basis for capacity-building at the grass roots level to address concerns of the poor, marginalised and other vulnerable communities to water security and seek to understand the dynamics of adaptation in the specific locations, for action and policy agenda at the regional level. It will build their capacities to cope with climate change induced water in-security.

[www.saciwaters.org/periurban](http://www.saciwaters.org/periurban)

### Coordinating Institution:

The project is being coordinated by **SaciWATERS**, Hyderabad, India. SaciWATERS focuses on transforming water resources knowledge systems, key ideas being an interdisciplinary approach to understanding water resources issues, from a pro-poor, human development perspective, with an emphasis on exchange, interaction and collaboration at South Asia level.

### Partner Institutions:

**Bangladesh University of Engineering and Technology (BUET)** is the oldest and leading university in Bangladesh in the area of technology. IWFM is a premier institute for the advancement of knowledge and development of human resources in water and flood management.

**Nepal Engineering College (NEC)** was established in 1994, as a non-profit organization under private sector initiative, to function as center for advanced learning in engineering and allied sciences. It has been offering the Interdisciplinary Water Resources Management (IWRM) Program since the beginning July, 2007 under the support of Crossing Boundaries (CB) Project funded by Government of the Netherlands.

### Project Support:


This project is supported by Canada's **International Development Research Centre (IDRC)**. IDRC is one of the world's leading institutions in the generation and application of new knowledge to meet the challenges of international development. For nearly 40 years, IDRC has worked in close collaboration with researchers from the developing world in their search for the means to build healthier, more equitable, and more prosperous societies.

#### Project Partners

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