Understanding Peri-urban Sustainability: The role of the resilience approach

Shova Thapa, Fiona Marshall and Sigrid Stagl

Resilience Approach

Understanding Peri-urban Sustainability: The role of the resilience approach

Resilience is a term that is widely used by scholars from different disciplines, who promote action research between science and policy. This paper is largely concerned with how resilience approaches can be used as a practical tool in helping to understand complex dynamic socio-ecological systems in an urbanising world and, in particular, how resilience approaches can contribute to initiatives with normative development agendas to enhance environmental integrity and social justice.

Some key debates around differing understandings and uses of the term resilience are summarised, and criticisms discussed. An initial case study demonstrates how the resilience approach can be a useful tool in understanding key interactions between social and ecological systems that impact on the management of protected areas. Further case studies examine how resilience approaches might help in understanding more complex peri-urban situations, characterised by increasing social exclusion and environmental degradation. A final case study from Varanasi India, examines relationships between water management in the peri-urban interface and urban food systems. It utilises a resilience framework to illustrate the lack of recognition by formal institutions of actual peri-urban water use practices and the many informal transactions that occur, and to highlight some implications in relation to urban food security, environmental policies and particular marginalised groups. These examples seek to demonstrate opportunities for the use of resilience approaches as an integral part of initiatives that seek to identify opportunities for enhancing sustainability (in relation to environmental integrity and social justice) in dynamic urbanising situations.

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Summary

Resilience is a term that is widely used by scholars from different disciplines, who promote action research between science and policy. This paper is largely concerned with how resilience approaches can be used as a practical tool in helping to understand complex dynamic socio-ecological systems in an urbanising world and, in particular, how resilience approaches can contribute to initiatives with normative development agendas to enhance environmental integrity and social justice.

This paper begins by summarising some of the key debates around differing understandings and uses of the term resilience, and then focusing on socio-ecological resilience, uses an empirical case study of Bardia National Park in Nepal to demonstrate how a resilience approach can be a useful tool in understanding key interactions between social and ecological systems that impact on the management of protected areas. This first example, where there is a recognised need to build resilience in a situation with high natural capital, but also high levels of poverty, illustrates how important variables and interactions, which tend to be overlooked, can be highlighted through a resilience approach, and how this can influence conservation policies and management plans.

Some criticisms of the resilience approach are considered, particularly in relation to its apparent ambiguity concerning for whom and what resilience is aimed. The relationship between resilience and sustainability is briefly discussed, and, in particular, how resilience might contribute alongside other established theories and approaches in understanding various dimensions of sustainability and how it might be sought.

The paper develops the use of the resilience approach by focussing on complex peri-urban situations, characterised by increasing social exclusion and environmental degradation, where conflicting priorities for development are inevitable. The flow of resources, and range of processes, from not only within the system (peri-urban areas) but also from outside the system (urban and rural) exemplifies the complexity and potential of multiple states in the peri-urban interface. A second case study examines water use conflicts in peri-urban Chennai, illustrating how a resilience framework can highlight the impact of actions of public resource providers on resource dynamics and less advantaged resource users; relationships that are often overlooked. A final case study from Varanasi India, adds a further level of complexity, in examining relationships between water management in the peri-urban interface and urban food systems. It utilises a resilience framework to illustrate the lack of recognition by formal institutions of actual peri-urban water use practices and the many informal transactions that occur, and to highlight some implications in relation to urban food security, environmental policies and particular marginalised groups. These

examples demonstrate how resilience approaches can be a useful component in initiatives that seek to identify opportunities for enhancing sustainability (in relation to environmental integrity and social justice) in dynamic urbanising situations.

1. Introduction

The Millennium Development Goals are associated with improved management of global resources and equity in resource allocation. In order to achieve them, a better understanding of the dynamic properties of environmental and social systems and their ability to respond to change is essential. Following the Brundtland Report (1987) which put the goal of Sustainability[1] onto political agendas, much analysis has focussed on the conflicts between socio-economic and environmental goals. Systems perspectives are being used increasingly to address problems related to representations of social, economic and environmental dimensions of sustainability, where Sustainability is '*the capability of maintaining specified values of human wellbeing, social equity and environmental quality over indefinite periods of time*' (Scoones *et al*. 2007:35). Hence, it is a process and ability to deal with change in constructive ways.

The Millennium Ecosystem Assessment (2003) also perceives Sustainability as a process, and suggests increased attention to system characteristics such as robustness, vulnerability, resilience, risk and uncertainty, which determine the ability of a particular system to adapt to and benefit from change. These system characteristics are themselves challenging to analyse. With the focus on Sustainability, we need to study coupled social-ecological systems[2] understood as integrated systems in which the dynamics of the social and ecosystem domains are strongly inter-linked (Liu *et al*. 2007b; Norgaard 1994); and whose strong reciprocal feedbacks mean that they are complex adaptive systems (Gunderson and Holling 2002). As social and ecological systems are strongly linked, it is important to understand the impact of changes on these systems; their feedback during such changes and how humans adapt to them for long-term Sustainability of social-ecological systems. Because sustainable development involves management of global resources and human well-being, it is a social, ecological and economic problem for which there is a need to integrate and understand the dynamic interlinkagees as social-ecological systems (Holling 2000).

Stirling (2007:5) argues that '*stability, durability, resilience and robustness are each individually necessary and collectively sufficient for the quality of Sustainability in social-ecological systems*'. In this paper we are focussing on the contribution of established resilience approaches to understanding socio-ecological systems and their sustainability, whilst recognising the need for integration with these

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[1] Capital S for sustaining specific attributes as Sustainability is a dynamic process.

[2] The term 'coupled human-environment systems' (Turner *et al*. 2003), social-ecological systems (Gallopin *et al.* 2001) and social-ecological systems (Berkes and Folke 1998) are used interchangeably to mean the integrated and interdependent nature of social and ecological systems.

other properties. A resilient system can adapt to changes, where adaptability is the capacity of actors to respond to the changes that influence resilience by changing the structure and functions of the system; and, where extreme change may even transform the system, i.e. create a new system. The adaptability and transformability of a system is dependent on the system's resilience, our focus in this paper.

The essence of the resilience approach among other approaches such as complex adaptive system theory, co-evolution theory, and actor-network theory, is that it not only helps to understand the interaction between the system components and how they would co-evolve in the presence of change; but also specifically allows one to identify how far the present state of the system can maintain the structure fulfilling the required functions and services without major changes before moving to other states. To clarify what 'states' mean, we use a definition by Walker, '*the state of a system at a particular instant of time is defined as the collection of values of the state variables at that time*' (Walker *et al*. 2002:5). In a complex system, 'states' is understood as a characteristic of a system rather than its state.

Building resilience in situations with high natural capital, but also high levels of poverty, is a pressing need in the pursuit of Sustainability. The peri-urban situation, which is characterised by increasing social exclusion and environmental degradation, is a good example here. Peri-urban places are complex transition zones, where conflicting pathways for development are inevitable, and where there is increasing marginalisation of vulnerable groups (STEPS 2008). This paper explores whether the use of a resilience framework would add to our understanding of the peri-urban interface in relation to resource management and Sustainability.

This paper is organised in four main sections. Section 2 explores various definitions of resilience. Section 3 discusses the theoretical underpinnings of resilience as an approach, followed by a case study of a protected area explaining resilience as a systems property, within a conceptual framework of social-ecological systems. This case study illustrates how important variables and interactions, which tend to be overlooked, can be highlighted through a resilience approach, and how this can influence conservation policies and management plans. We then review some of the critiques of the resilience approach and particularly its applicability in the context of Sustainability which integrates environmental and social justice priorities. Section 4 builds on the first case study by discussing the potential use of the resilience approach in understanding the dynamics of the peri-urban interface illustrating how a resilience framework can highlight the impact of actions of public resource providers on resource dynamics and less advantaged resource users; relationships that are often overlooked. A final case study from Varanasi India adds a further level of complexity, in examining relationships between water management in the peri-urban interface and urban food systems. In Sections 5 and 6 we draw some lessons from the case studies for the contribution of the resilience approach in understanding potential alternative policy and institutional approaches to support poor and marginalised communities and progress towards a longer-term Sustainability agenda. Potential ways to strenghthen the contribution of a resilience framework in understanding pathways towards the management of the peri-urban interface that enhance environmental integrity and social justice are emphasized.

2. Resilience: Origin, definitions and ambiguous meanings

The concept of resilience emerged from ecology and was first used for the study of ecosystem management. Using it as a descriptive core concept in a population model, Holling (1973:17) states that '*resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables and parameters, and still persist.*' Emphasising the persistence and absorbance of changes, Holling illustrated that ecological systems are beyond the 'stability-equilibrium state' and argued that systems exist in multiple stability domains or 'basins of attraction' in natural systems (Holling 1973). As a system at a particular space and time is influenced by interactions between the system components, ecological processes and events such as disturbances, multi-stable states are inevitable (Folke 2006; Walker *et al*. 2004). With the existence of multi-stable states, Holling used the word resilience, along with the variables and parameters, to illustrate the persistence of a system before it moves to other states. For example, a savannah can either be in a stable grassy state or a stable woody state depending upon the influence of driving factors, such as fire, rainfall and grazing pressure. Thus, resilience of a savannah at any time is the persistence of a woody state during a change such as fire or grazing before moving to a stable grassy state (Walker *et al*. 2002).

Resilience may be related to engineering resilience or ecological resilience. The time taken by the system to return to an equilibrium state after a disturbance, i.e. speed of return to the equilibrium state (Pimm 1991) is referred to as 'engineering resilience' (Holling and Walker 2003). Resilience in this case refers to the dynamics close to some form of equilibrium and is largely related to the stability of a system (Brand and Jax 2007). Ecosystem or ecological resilience refers to dynamics away from equilibrium states with the possibility of multiple states, and is defined as the amount of change a system can absorb before moving to another state maintained by different sets of structures and functions (Holling 1973). The definition of resilience in this paper is closer to ecosystem resilience, which highlights that systems are dynamic with multiple equilibrium states.

Brand and Jax (2007) argue that resilience is one of the most used concepts in sustainability, and has been used widely by various researchers from different disciplines to analyse ecological, social and social-ecological systems promoting research and policy in science. They further state that through the advancement of the usage of the term '*…both conceptual clarity and practical relevance are critically in danger…… the original ecological meaning of resilience is diluted as the term is used ambiguously and in a very wide extension*' (Brand and Jax 2007:1). Highlighting the danger for the vagueness of the resilience concept they identify ten definitions falling in three categories and ten classes. These ten definitions start defining resilience as a descriptive ecological concept and goes beyond, incorporating a more vague meaning to hybrid and a normative concept (for details please refer to Brand and Jax 2007). Each of the definitions emphasise different aspects of resilience used for different intentions by ecologists, sociologists and political scientists making resilience a boundary object[3]. Brand and Jax in their paper explain both advantages and disadvantages of using resilience as a boundary object. In this paper we do not review an array of definitions but do discuss and define the terms that we will be using.

Using the ecosystem resilience definition as described above, we understand resilience as the capacity of a system to absorb shocks while maintaining the essential functions, structure and feedbacks. Here resilience is used as a descriptive concept. Resilience in social systems refers to the ability of the actors, their production systems and institutions to remain flexible and adaptive enough to change in the face of perturbation and exposure to risk (Adger 2000; Vayda and McCay 1975). Thus, the human element adds to resilience since humans, through their ability to visualise, foresee and plan, can enhance the resilience of a system. For instance, when a drought occurs in a social system based on agriculture, a resilient social system will include options, such as alternative, drought resistant crops, development of reservoirs and irrigation techniques, to withstand the shock and maintain the system functions in a new environment. Although the human element is an important part of social resilience, the resilience framework cannot explain human behaviour. This implies that the resilience framework can only be used to understand how human behaviour affects the resilience of a system in which the humans are embedded. Resilience in social-ecological systems refers to the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks (Walker *et al*. 2004). Resilient social-ecological systems incorporate diverse mechanisms for living with and learning from change and unexpected shocks, thus adapting to the disturbance (Adger *et al*. 2005). This implies that social-ecological resilience is not only about the change but also the interplay of systems brought by the change and reorganisation within the system through social learning and innovation. Maintaining and enhancing the resilience of social-ecological systems, therefore, is an important element of Sustainability. In the context of social-ecological systems, resilience moves towards a more normative concept than a descriptive one.

Scholars argue that resilience has not been fully developed to use as a theory. Anderies, Walker *et al*. (2006:2) suggest that '*resilience ideas do not comprise a theory intended to explain the behaviour of social-ecological systems, and so might be termed a resilience framework or resilience approach.*' Similarly, Carpenter and Brock (2008:1) stress that, '*Resilience is a broad, multifaceted, and loosely organised cluster of concepts, each one related to some aspect of the*

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[3] A boundary object is a concept used in sociology to describe information interpreted in a broader meaning and in different ways by different communities. Boundary objects are both adaptable to different viewpoints and robust enough to maintain identity across them (Brand and Jax 2007).

interplay of transformation and persistence. Thus, resilience does not come down to a single testable theory or hypothesis. Instead it is a changing constellation of ideas, some of which are testable through the usual practices of natural or social science.' Therefore, in this paper we would use the term resilience framework and resilience approach interchangeably rather than a resilience theory for a theoretical concept of resilience.

Resilience approach is a theory of change and seeks to understand how complex systems change, what determines the system's ability to absorb disturbances and the capacity of actors to learn from the change (Janssen *et al*. 2006). To understand the complexity of systems, it uses a theory of dynamic cycles, known as adaptive cycles that are linked across space and time (Holling 2001). Resilience framework comprises the measurement of these four ecosystem functions: growth or exploitation (r), conservation (K), release of creative destruction (Ω) and reorganisation (α) are organised into an adaptive cycle nested in a hierarchy across time and space known as 'panarchy'[4] (Gunderson and Holling 2002). Panarchy, '*used to describe the concept of evolving nature of complex adaptive systems, is the hierarchical structure in which systems of nature, and humans, as well as combined human-nature systems and social-ecological systems, are interlinked in never ending adaptive cycles of growth, accumulation, restructuring and renewal*' (Holling 2001: 392).

As the resilience approach is taken from ecosystems, four key features of ecosystems provide the underlying assumptions (Gunderson and Holling 2002: 25-27). First, change is episodic with periods of slowly accumulating natural capital punctuated by sudden release or reorganisation of components. As change is neither continuous nor gradual, three different kinds of change have been identified: incremental change in the r and K phases, these changes is predictable; abrupt change in the transitions from K to Ω and α; and transformational change involving learning from previous changes (Gunderson and Holling 2002). Second, spatial and temporal patterns and processes are patchy and discontinuous at all scales. Third, ecosystems do not remain in an equilibrium state, rather they have functionally different multiple states. Fourth, institutions that are rigid, lack flexibility and focus on constant yields without considering the change lead to systems that break down easily in the face of disturbances. To apply the adaptive cycles model in systems other than ecosystems, two conditions needs to be met (Berkes *et al*. 2003). First, systems must be desirable in dynamic terms and second, they must have potential to move into the multiple states. Most of the human-environment systems meet these two conditions for the application of adaptive cycles.

Building resilience in social-ecological systems requires four important factors (Folke 2003). The first is learning to live with change and uncertainty. Learning and living with change requires observations in the past and then adaptation

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[4] The diagram is a represented by a 'figure eight' model. For detail please refer to Gunderson and Holling 2002.

to future changes. Second, nurturing diversity as diversity in all forms provides seeds for new opportunities in the renewal cycle, increasing options to cope with shocks and stresses (Berkes 2007). Third, combining different forms of knowledge for learning, which will not only increase capacity to learn but also provide better understanding for the management of resources (Abidi-Habib and Lawrence 2007). And finally, creating opportunities for self-organisation during renewal and reorganisation such as community-based management and adaptive co-management.

3. Theoretical Background: Resilience approach

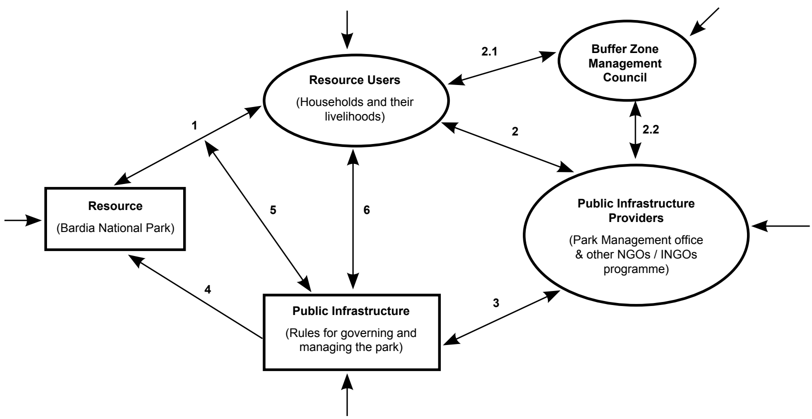
3.1. Human-nature interactions: Conceptual strengths and empirical gaps

The problems we face related to environmental change globally highlight the need for research focussing on feedbacks in the relationships between humans and the environment. However, many studies dealing with interactions between mankind and nature have failed to explain the complexity of social-ecological systems (Liu *et al*. 2007a). One reason for the lack of progress in these studies is the still strictly separate ecological and social sciences (Rosa and Dietz 1998). Studies focussing on social and ecological system interactions are complex and do not fully address the problems faced by communities in natural resource management (Berkes *et al*. 2003; Berkes and Folke 1998). Most research on the complexity of social-ecological systems is conducted by natural scientists and there is little empirical work to complement these conceptual studies (Liu *et al*. 2007a). There is a critical need for research that focuses on the interactions and interplay among the social, economic and cultural issues of environmental change. Understanding the interplay within social-ecological systems encompasses structures, regulatory mechanisms, and decision processes at different social levels, highlighting the role of institutions in diverse forms (Ostrom 2005). It also includes direct and indirect feedback loops describing the impacts of social, ecological, economic and technological activities upon environmental systems and the consequences of their impact on social systems (Berkes *et al*. 2003; Gunderson and Holling 2002).

The need to focus on complex social-ecological systems highlights the need for an innovative approach, which provides a context in which to understand the interplay and interaction between social-ecological systems. Researchers have argued that the resilience approach is one of the strongest concepts to understand the dynamics of social-ecological systems (Anderies *et al*. 2006; Walker *et al*. 2006a). Here, dynamics refers to changes and interactions occurring within and between the systems. Some of the strengths that make it unique include: i) resilience allows analysis of the changes in social-ecological systems and the determination of their ability to survive the disturbance (Janssen *et al*. 2006); ii) resilience helps to understand the dynamism of systems on multiple scales of interactions (Walker *et al*. 2004); iii) resilience supports our understanding of how social-ecological systems can cope with, adapt to and shape change for Sustainability (Folke 2006) and guide the adaptive capacity of humans in social systems (Young *et al*. 2006); and iv) resilience facilitates the integration of other theories for a better understanding of the dynamics in social-ecological systems on multiple scales (Anderies *et al*. 2006). Moreover, research in social-ecological systems focuses not only on appropriate disciplinary and interdisciplinary methods, but also on transdisciplinary methods, integrating knowledge from actors embedded in the various levels of social systems; the resilience framework is thus an important tool (Walker *et al*. 2006b). We will use the following case study of a protected area to illustrate our understanding of social-ecological resilience, where resilience has been used as an indicator to examine roles of institutions.

3.2. Illustrating social-ecological resilience: Case study of Bardia National Park

Our case study for social-ecological resilience analysis is one of the 'hot topics' in natural resource management, i.e. protected areas. According to Barbier *et al*. (1994) building resilience in protected areas has been a challenge for protected area governance. To address the challenge this study explored whether institutions play any role in providing social-ecological resilience through biodiversity conservation and community well-being in Nepal's Bardia National Park (Thapa, 2008). Anderies *et al*. (2004) argue that the interaction between households and their livelihoods, and institutions - both providers (government bodies) and rules - are key variables influencing the resilience of social-ecological systems. They stress that these aspects have been overlooked, despite their importance for understanding the social-ecological system. To try to fill this gap, this research used the conceptual framework of social-ecological systems based on Anderies *et al*. (2004) to study social-ecological resilience. Exploring the interactions between households, institutions and the national park, figure 3.1, this research investigated livelihoods, dependence on natural resources, conflict and attitude, park vegetation status and biodiversity conservation institutions in Bardia.



In the figure, numbered arrows (1-6) are key interactions within the social-ecological system
Other arrows specific to the box denotes disturbances both external and internal

Figure 3.1 Conceptual framework of the social-ecological system (components and their interaction) in Bardia National Park, Nepal.

In figure 3.1[5], the resource is Bardia National Park, its wildlife and forestry products, which are protected by rules, but prior to the Park's establishment, were used by the communities in the area. The human components include resource users (households and their livelihoods), public infrastructure providers (park management office and officials and other NGO and INGO offices). We include the Buffer Zone Management Council because members of the council come from the communities, and the services provided by the Public Infrastructure Providers trickle down through the council to the communities. We found that the council was one of the important components of the social-ecological system that connects communities to the Park and that the Park benefits from and supports collective action among households within the Buffer Zone. Therefore, its inclusion in the framework is necessary. Key interactions occurring between the components described above in the social-ecological system of Bardia are presented in table 3.1.

[5] In figure 3.1, the components are divided into two parts with two shapes (circle and rectangle); components in circles are composed of humans; components in rectangles are resources and public infrastructure in the form of rules.

Table 3.1 Interactions involved in the social-ecological system

Link	Interaction occurring in the case of Bardia	Problems Occurring
1. Between resource and resource users	Wildlife disturbance to households' farmland, destroying crops; households illegally extracting resources from the Park to satisfy their needs	Illegal resources extraction has significant impact on the Park's forest diversity, richness and structure
2. Between resources users and public infrastructure providers	Development projects were provided to minimise the conflict which led to the establishment of Buffer Zone Management Council (BZMC) as a legal body for equity distribution of revenue in the form of development projects, Buffer Zone Community Forest establishment and annual grass-cutting programme Between users and BZMC Households felt close relationship with the Council Between BZMC and public infrastructure providers	Incentives provided by the INGOs and NGOs in the form of community-based conservation projects have not been able to target the essentials for livelihood strategies. Buffer Zone Forest has not been able to satisfy the rising demands of households and there are villages which do not have Buffer Zone Forest so are dependent on Park resources for their livelihoods Problem between chairperson of BZMC and Buffer Zone Community Forest. Contention over the flow of money for community development Lack of coordination between BZMC, park managers and officials of other NGOs and INGOs. Competition among programmes to show higher impact focussing on a few households rather than the whole community
3. Between public infrastructure providers and public infrastructure	Monitoring and enforcing rules	Lack of community participation in decision-making process

Link	Interaction occurring in the case of Bardia	Problems Occurring
4. Between public infrastructure and resource	Rules employed for biodiversity conservation within the Park	Increased wildlife populations after protection led to the competition between wildlife and households livelihoods Park-people conflict due to interaction between household livelihoods and wildlife interference as well as illegal resource extraction. Households in constant conflict with the Park managers
5. Between public infrastructure and resource dynamics	Impact of rules on the resource-livelihood dynamics	Change in the rules caused disturbance to the social-ecological system of Bardia resulting in a short term positive impact on the ecological system (increase in wildlife population) and negative impact on the communities (restriction on resource use). However, the negative impact on the communities pushed the vulnerable communities to illegally extract the resources impacting on the forest structure and diversity, which in the long run will affect the habitats of the animals
6. Between public infrastructure and resource users	Strict rules for wildlife protection and provision of development projects for community development. Compensation for communities	Negative attitudes towards the Park and conflicts due to the problems faced by wildlife and no rules to support households facing crop damage or property loss. Compensation involves a lengthy process to make a claim

Table 3.1 presents the interactions in the social-ecological system of Bardia and the problems that arose and affected all components in the social-ecological system. Among these interactions, the most important was between public infrastructure and resources (no. 5) and related to change in the rules affecting the resource dynamics at Bardia National park, leading to loss of livelihood, illegal resources extraction and impact on the forest structure and diversity as well as conflict between community and the park management. Out of the total surveyed households in Bardia, 92% were based on agriculture as the main source of income; the park wildlife constantly interferes with this activity. Thus, any additional

change, such as drought, crop disease, etc. will lead to the collapse of the social system. To compensate for loss of livelihood they could perhaps start to keep cattle in large numbers, which means more illegal resource extraction, which in turn will exacerbate the Park-people conflict and impact on the Park vegetation. Adverse effects on the habitats, food sources and breeding grounds of wildlife will have a direct impact on wildlife populations.

There are development projects designed to support households to be less dependent upon the Park and to exploit a range of income generating activities, e.g. biogas, potatoes and vegetable farming, fish ponds, livestock rearing, skill training etc. However, there are conditions attached to these activities. For instance, to qualify for the installation of biogas a deposit of Rs.8000 is required, and livestock for the digesters (dung). For the poorest households, there is no chance of these requirements being met; many yearly incomes do not reach Rs.8000 in total for instance, and if the land owned is not enough to support their households they are unlikely to allocate part of it to fodder crops for cattle. We suggest that due to the application of inflexible rules with no allowance for different or changing conditions, the resilience in the social-ecological system of Bardia is diminishing and the system will collapse if hit by a major disturbance. In other words, the current situation in Bardia is undesirable in terms of the resilience of the social system.

An ideal scenario for Bardia would be households with diverse sources of income such that during shocks they would have options and opportunities to adapt to change. For the poorest households, more flexible institutions and more affordable conditions for the installation of biogas plants are needed. For villages outside the Buffer Zone Community Forest, Park management should coordinate with the Forest Department and convert national forests to community forests and release Park funds to help the communities to manage them. For villages that have no national forest, the Park should provide areas set aside within the Park or on its boundaries that could be converted to Community Forest land. There are many successful examples of Community Forests in the hilly regions of Nepal (Nagendra 2002; Pandit and Thapa 2004). Best practice from these examples of forest management could be imitated and adopted. As communities comprise diverse groups of individuals with different needs, interests and objectives, it is important that these differences are taken into account when implementing development projects, so that all groups of communities would benefit. Further, Park management should involve communities in the development of management plans in order to foster collective action and gain support for conservation programmes. Exploring the different interactions and problems that exist among the components of the social-ecological system in Bardia helps to explain the processes of community behaviour such as illegal resource extraction, attitudes to the Park, impact on forest structure, etc. A better understanding of these processes will help Park managers to identify areas where a different management approach is needed in order to support social-ecological resilience in protected areas.

3.3. Critics of the resilience approach: Normative notions

Development scholars criticise resilience for its focus on bio-physical systems and its ambiguity concerning whom and for what purpose it is aimed (Leach 2008). The resilience framework was developed to analyse ecosystems (Holling 1973) and was a breakthrough in indicating that there are multiple states within an ecosystem; that the ecosystem is not in a state of equilibrium, but can be in multiple states depending upon resources and agents (Holling 2001). This led to the development of the resilience approach and adaptive cycles in which resilience was used to analyse social and then social-ecological systems (Berkes *et al*. 2003; Berkes and Folke 1998; Gunderson and Holling 2002). However, resilience in the ecosystems perspective tends to dominate ecological thinking about the social-ecological system, and its utility is limited mostly to social-ecological systems (Turner 2008). In the example of the collapse of the Central Maya lowlands, Turner argues that although resilience can be used to explain events and changes in ecological systems, it cannot explain human behaviour and why and what led to the human activity involved in this example.

In addition, the focus of resilience is on the ability of systems to cope with changes rather than on normative concepts, and can be seen as a system property, with the implication that, depending on ones perspective, achieving resilience may or may not be good for certain kinds of systems (Berkhout 2008). As mentioned above, Brand and Jax (2007:9) highlight that ambiguous and vague meanings of resilience similar to sustainable development may create '*hindrance to scientific progress*', which makes it a difficult concept to operationalise and apply. This implies that researchers from diverse backgrounds try to apply it to give emphasis to certain variables at the expense of others.

Leach (2008) argues that researchers following the resilience approach tend to bundle together various attributes that are important for social-ecological system Sustainability. As the resilience approach is a theory of change and seeks to understand the source and role of change (Redman and Kinzing 2003), it is important to describe the change or disturbance and study the dynamics of disturbance to understand its impact on the social-ecological system. Depending upon the kind of disturbance, it can have different impacts on the governance as one kind of disturbance could lead to control of only one measure, neglecting other important response drivers. Focusing on one specific control might reduce other important drivers, which are necessary to manage the system. For instance, water management during flooding could focus on control strategies on maintaining water flow. Maintaining water flow could be difficult as it is highly uncertain depending upon the amount of rainfall. However, focusing only on maintaining water flow could neglect the response strategies important to adapt to flooding such as building structures to cope with increasing water flow. Therefore, to address different kinds of changes, the STEPS pathways approach unpacks the resilience approach into four dynamic system properties that are '*individually necessary and collectively sufficient*' for Sustainability (Stirling 2007:5). The four attributes described by Stirling are stability, durability, resilience and robustness; they deal with the shocks and stresses, and perturbations that are internal and external to the system. Stirling (2007) argues that addressing each of these dynamic system properties helps governance systems to adapt to the change without losing the necessary system structure for achieving Sustainability.

Understanding these shocks and stresses, both internal and external to the system will lead to questions of what to do with the changes. The question of 'what to do with the changes' and what measures are needed to respond to such changes depend on the framings of the problems from different groups of actors, power, politics and institutions. Failure to address the issues of power and politics is regarded as one of the weakest points of the resilience approach. Hornborg argues that '*the discourse on resilience is oblivious not only of power, conflict and contractision, but also of culture*' (Hornborg 2009:255). The challenge lies in how to integrate the notions of power and conflict within the resilience approach.

3.4. Overcoming the criticism: Building on the strengths

To counteract these ambiguities and make resilience more meaningful to a particular context, i.e. societies and groups of people facing conflict, dilemma and uncertainty, we need to highlight the strengths of the concept from four aspects. Firstly, we need to integrate other theories to enable a better understanding of the interactions that occur in a social-ecological system; Nkhata *et al*. (2008), for example, argue that the use of resilience as an approach offers a better understanding of change in long-term relationships in collaborative management in social-ecological systems. In their analysis, they integrate the approaches of resilience and relationships theory to understand changes in long-term relationships and investigate how social relationships affect the collaborative process in resources management. Integrating other theories could facilitate the exploration of issues related to change, and the capabilities and institutions available to support such change. For instance, in a case study of Bardia National Park, Thapa (2008) uses the livelihoods approach, institutional analysis and a development framework and vegetation analysis to study the social-ecological resilience of Bardia. In response to arguments that resilience is a vague concept, we could argue that this vagueness, combined with the concept of resilience as a boundary object, facilitate communication across disciplines and between science and practice, in social-ecological systems analysis.

Secondly, in response to the criticism that resilience does not explain the social system and the behaviour of human beings, we would highlight the components of social systems. Unlike ecological systems, resilience in social systems is different and important (Holling and Walker 2003) in that humans and institutions, which are both components of social systems, have the capabilities to plan and prepare for the future (humans) and devise appropriate mechanisms in the form of rules and policies (institutions). This has both positive and negative aspects.

Because humans are able to plan, they can be better prepared for the future disturbances. However, this planning also gives them power to control and experiment with ecosystems (Berkes and Turner 2006), but makes it difficult to understand why they behave in certain conditions. One way to understand human behaviour in social-ecological systems could be through social processes such as social learning, social memory, mental models, knowledge system integration, envisioning and scenario building, leadership agents and actor groups, and social networks (Armitage *et al*. 2008; Beratan 2007; Berkes and Turner 2006; Fazey *et al*. 2007; Webler *et al*. 1995). Understanding these social processes enables adaptive governance of social-ecological systems during periods of change (shocks and stress) by connecting individuals, households, firms, organisations and institutions at multiple levels (Folke *et al*. 2005).

Thirdly, to make resilience more meaningful, the STEPS approach to framings is useful (please refer to Scoones *et al*. 2007; Stirling *et al*. 2007). For instance, to understand and respond to the question of 'resilience for whom?', it is useful to attach resilience to either a group of people or institutions and explore how certain groups seek resilience and have a particular need to be resilient under certain conditions (Leach 2008). Therefore, addressing the framings for the social-ecological system could provide a context (Scoones *et al*. 2007). For instance, as suggested by Scoones *et al*. (2007) different framings could represent different parts as well as multiple scales of a social-ecological system. In the case study of Bardia National Park by Thapa (2008), the social-ecological system comprising communities and the Park includes the contexts of different stakeholders, for example, livelihoods of communities, households dependent on the Park for resources, Park management, and the NGOs and INGOs for community development and biodiversity. Each context has different problems, issues and socio-economic, institutional and ecological influences. Similarly, context might also include different scales, such as household, social group, community, village, region and national levels.

Fourthly, as argued by Folke (2006) resilience is not only about the ability to cope with disturbance as explained by Berkhout (2008); it is also about the opportunities that change opens up for the renewal of the system's processes and the emergence of new pathways. This implies that resilience is about adaptation, uncertainty and flexibility, which allow for continuous development for long-term Sustainability. In the broader sense, the resilience approach allows us to learn how to live with change through continuous development in the presence of disturbance, and how to innovate and transform into a new desirable state. The importance of the resilience framework is its focus on form; equilibrium states to multiple states of change and static systems to dynamic systems (Berkes *et al*. 2003). Understanding these forms leads to the identification of variables that affect the dynamics and ability at various scales, which in turn helps to understand how the system manages the changes occurring. In social-ecological systems perspective, it is understanding about how human behaviour during those dynamic periods influence system resilience. In addition, Leach (2008) argues that the resilience approach can be enriched by including an analysis of multiple actors, their interactions, their strategies, the flow of information within and between systems and including the ‘power and politics’ development debates to enable adaptation, social learning, flexibility and empowerment of actors in social-ecological systems. This implies that by exploiting the strengths of resilience and including a framing from the perspective of the social group under study along the lines of the STEPS Centre, resilience can act as a normative concept and offers prospects for a better understanding of the dynamics of the peri-urban interface.

4. Resilience approach to the peri-urban interface

In the context of criticism of the resilience approach discussed above, how might the resilience approach be utilised to help understand the dynamics of the peri-urban interface and implications of various interventions in terms of Sustainability. The answers lie in the complex nature of the peri-urban interface which current approaches, such as political ecology and cultural ecology, alone cannot deal with. Through the lens of resilience, ecological systems are dynamic with the potential for multiple states all encompassing surprise and uncertainty in the adaptive cycles including repeated processes of growth, conservation, renewal and reorganisation (Holling 2001). Dynamism and the potential for multiple states, and stress are all related to and are characteristic of the peri-urban interface. The complex and sometimes ambiguous meanings and contexts of the term peri-urban make it difficult to define (Butterworth *et al*. 2007; Marshall *et al*. 2009); we do not attempt such a definition here[6]; rather, we focus on and highlight characteristics of the peri-urban situation explaining the relevance of the resilience approach, in relation to understanding its dynamics and with a normative sustainability agenda.

Peri-urban areas comprise mixed and disproportionately large populations of poor households and producers based on natural resources and ecosystem services essential for and used by both urban and rural communities (Allen *et al*. 2006a). Peri-urban zones are regarded as complex 'transition zones' as areas that are moving from rural to acquiring urban characteristics involving a '*dynamic flow of commodities, capital, natural resources, people and range of processes leading to intensification of rural and urban linkages*' (STEPS 2008:1). This implies that peri-urban areas are rapidly changing as they move towards urbanisation, with intense impacts on urban and rural development which conflict with production as well as demand processes. To understand this highly dynamic state and its multiple levels involving urban and rural influences and experiencing change from not only within the system (peri-urban areas) but from outside the system (urban and rural), we need an approach that provides an understanding not only of the changes occurring in the system, but also the system attributes that are important for the functioning of the system for Sustainability.

Through the lens of the resilience approach we explore the complexity of the peri-urban interface with the example of water resource management. In 2010, half the world's population lives in urban areas, with the highest percentage of the population in Asia than in any other continent. With this increasing population and urbanisation, meeting water demand is a tremendous challenge being faced by many developing countries (Butterworth *et al*. 2007). In spite of technological innovations and infrastructure developments, supply of and demand for water

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[6] For detail on the definition of peri-urban, refer to Marshall *et al*. 2009.

has neither reached all levels of the community nor systematically met demand. This gives rise to contested situations between different sectors, such as inter-sector (agriculture and industry) and intra-sector (urban, peri-urban and rural). Unparalleled urban expansion in the developing world is predicted and, linked to this growth and the creation of new opportunities, will be the concentration of poverty in peri-urban zones creating disturbances in the service sector such as health and sanitation (UNFPA 2007).

4.1. Water use conflicts: Diverse needs and interests

The most rapid urbanisation takes place at the edges of cities - between urban and rural areas, or the peri-urban fringe (OECD 1979). This urbanisation and expansion has a direct impact on the peri-urban fringe leading to conflicts over basic needs, such as water. Using the conceptual framework of the social-ecological system from section 3.1, we explore the key issues surrounding water management in Metropolitan Chennai. Chennai is regarded as one of the most water-stressed cities in India creating scarcity in supply and conflict among users (Butterworth *et al*. 2007). However, scarcity of water in Chennai is not only related to physical but to social scarcity also. As the formal system disregards the more informal systems of water use of rural farmers and urban resource users, there are four key components involved in peri-urban water management (figure 4.1).

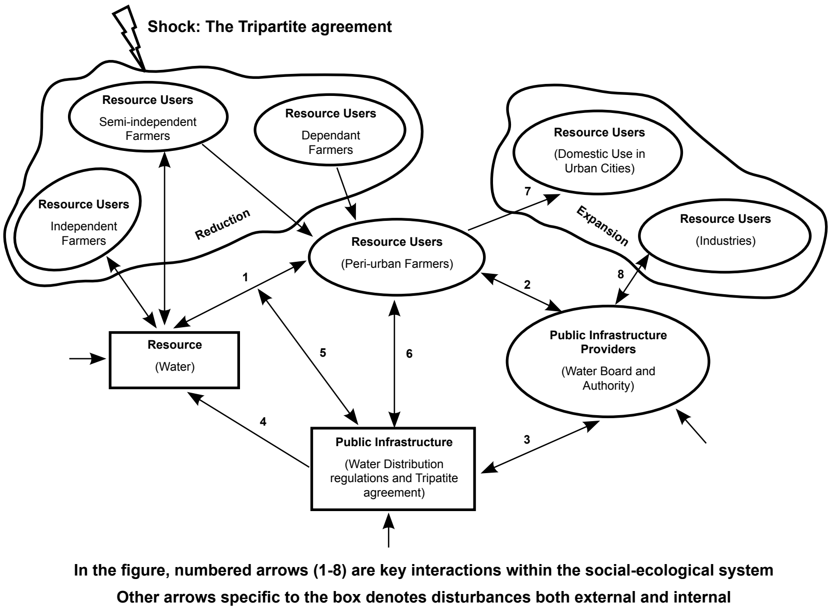


Figure 4.1 Conceptual diagram of social-ecological system involving water management in peri-urban areas

In figure 4.1, the social-ecological system of water management includes water as a resource used by communities, the resource users. These users are at the centre of the system because they are farmers who sell water from wells on their land. However, there are also indirect users, e.g. farmers in peri-urban areas who are dependent on the farmers selling water. Thus these water users fall into three categories: i) dependent farmers; ii) semi-dependent farmers, and iii) independent farmers, left top part of the figure. In addition to these farmers in peri-urban areas, there are indirect users in the urban centre who need water for domestic and industrial purposes. However, the interesting point to note is that the expanded resource users are linked with the public infrastructure provider, top right part of figure 4.1. The use and distribution of water to various consumers is regulated by the public infrastructure provider, the Water Board and the Water Authority, through water distribution regulation and tripartite agreements related to the public infrastructure. However, the amount of water distributed is controlled by the public infrastructure provider, and this produces conflicts. Expansion of indirect resource users (top right part of the figure) and interactions between different components have led to conflicts over water, while contraction of informal previous users (top left part of the figure) has led to the livelihoods of peri-urban farmers being threatened. Finally the water table is being affected, leading to water scarcity and long-term drought. Different interactions occur between these components during water extraction and distribution creating various outcomes (table 4.1).

Table 4.1 Interactions between the components of social-ecological systems of water resource management in Chennai, India.

Link	Interactions between different components leading to water use conflict, change in land use and decline of water table
1. Between resource and resource users	Availability of water to the water selling farmers; this availability of water provides income and gives them the power to choose among consumers.
2. Between resources users and public infrastructure providers	The Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) is in charge of supplying water to the entire area and some of the adjacent urban and rural local bodies in the metropolitan region, thus covering households, government institutions, industries and also slums. The CMWSSB hires wells from farmers to extract water and distribute to their best consumers bringing revenue for the board
3. Between public infrastructure providers and public infrastructure	Water purchasing agreements regulated by tripartite agreements.[7] The CMWSSB hire wells from the farmers to purchase water.
4. Between public infrastructure and resource	Water extraction from wells owned by the CMWSSB through the Tripartite Agreement.
5. Between public infrastructure and resource dynamics	Unequal income distribution between water selling farmers and dependent farmers leading to conflict, land use change and over-exploitation of water.
6. Between public infrastructure and resource users	The agreement led to an 82% increase in the income from water selling by farmers, and caused disruption to the livelihoods of dependent farmers reducing their incomes by 59%.
7. Between resource users and urban cities	Expansion of new resource users paying higher amounts in urban cities leading to over-exploitation of water.
8. Between public infrastructure provider and industrial sector	Increase in revenue of the CMWSSB with higher amounts of water diverted to the industrial sector by the CMWSSB leading to more farmers joining the agreement.

Before the Tripartite Agreement was signed in March 2000, the peri-urban social-ecological system including water management and farming was a resilient system with dependent farmers able to earn a livelihood by farming, and selling farmers making a good income. The system was resilient for those farmers who were semi and fully dependent upon water resources and also to the farmers who were selling water to farmers and the government. The system was socially

[7] According to the agreement, the CMWSSB pays a certain amount of money to the farmers in exchange for water. For more detail see Ruet *et al.* 2007

resilient to shocks such as social conflict between water selling farmers and water buying farmers due to regular flow of income and water to both parties; and ecologically resilient to water deficit as there were limited users. However, the Tripartite Agreement signed by the water selling farmers brought a shock to the social-ecological system of farmers, figure 4.1. The agreement not only agreed to higher prices for the water from these wells, it also encouraged farmers who previously had sold their water to the dependent farmers to also sell to the government, thus reducing the amount of water available for the farmers. However, the high prices involved in the agreement led to the expansion of users in the industrial sector and the urban centre. This also promoted a change in the ecological system. The dependent farmers bought water for irrigation, and controlled the use and extraction of underground water. However, water sold to the industrial and urban areas doubled between 2000 and 2001/02 leading to sources being over-exploited. Without water for irrigation, dependent farmers could not continue to farm: a number of farmers ceased to cultivate all together whilst others changed their cropping practices from rice to crops requiring less water (Ruet *et al*. 2007).

This had a serious impact on the patterns of land use in the area, as cultivation was abandoned by both dependent farmers and water selling farmers, although for different reasons. Dependent farmers were forced to abandon cultivation due to lack of water, reducing their income by 59% from 1999 to 2002 (Ruet *et al*. 2007). Water selling farmers abandoned farming due to the high incomes they were obtaining from selling water; their profit was equivalent to 'three seasons of cropping for 11 acres per farmer' (Ruet *et al*. 2007:117), and increased their incomes by 81%. According to Ruet *et al*. (2007: 116), '*the agreement fostered the economic integration of the richest farmers to the economy of the metropolitan area, and expanded urban-oriented land use to the rural areas, expanding the imprint of the city*'. In addition to the changing land use pattern, over-exploitation of water sources to fulfil urban and industrial needs has led to a reduction in the water table which is affecting long-term ground water supply in the region, the impact of which has started to emerge as continuous drought. As Butterworth *et al*. (2007: 57) claim, because of high level ground water extraction, since 2000 Chennai and its peri-urban villages are exposed to '*continuous drought leading to a serious decline in the water table and water yields*'.

Thus, apart from the interlinkages and the needs of other stakeholders, the agreement brought changes to the system, leading to loss of livelihoods for some stakeholders, huge incomes for other stakeholders creating social exclusion, changes in cropping patterns and land use practices, decline in the water table and underground water, changes to socio-economic integration and expanding urban oriented life styles and land use, and increase in water users. The changes in the governance and control of the system with no consideration for the numerous dynamics and the interplay among different components has produced vulnerability and conflict among stakeholders and created a group of 'peri-urban water poor' (Allen *et al*. 2006b) and threats to long-run Sustainability.

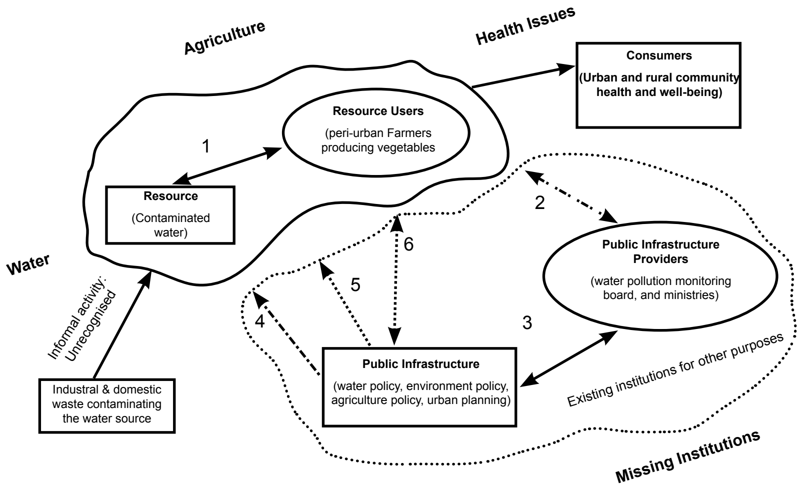
In this context, from a resilience point of view, the system is highly vulnerable to shocks such as regional drought, social conflict between different stakeholders with loss of livelihoods and it is also unstable as resources are being depleted. Some of the actors in the system do not have a means to cope with this change. This vulnerable system is likely to result in less production of fresh food, affecting both the livelihoods of poor farmers as well as the supply of fresh perishable food items to urban residents. Thus, the resilience approach emphasises development of the capacity of systems to move through dynamic social and ecological change, focussing on their components and the interactions among them. This is important as many existing management approaches and tools tend to focus on controlling one component, in this case, probably the Tripartite Agreement, neglecting the interactions among systems. In assuming a 'balanced state' policy makers tend to focus on finding 'best practice' solutions in order to control the system.

The resilience framework was useful here in explaining the interrelationships between different actors and systems. It has not made a direct contribution to understanding, 'who should act upon those changes and for whom' but could be key in illustrating key interactions as part of a wider exercise of research and consultation.

4.2. Peri-urban waste water use: Resilience of urban food systems

Our final case study adds a further level of complexity in examining relationships between water management in the peri-urban interface and urban food systems. It also utilises a resilience framework to illustrate the lack of recognition by formal institutions of actual peri-urban water use practices and the many informal transactions that occur. It then goes on to highlight some implications in relation to urban food security, environmental policies and particular marginalised groups.

Failure of formal institutions to recognise the risks and opportunities related to waste water use in peri-urban farming has costs for people living in these, as well as urban and rural areas in Varanasi, India (Marshall *et al*. 2005). Contaminated waste water use is often an informal and illegal activity. Using the resilience approach, we present some of the key components and interactions involved, but ignored, in waste water use (figure 4.2).



In the figure, numbered arrows (1-6) are key interactions within the social-ecological system of Peri-urban agriculture
The broken arrows represent missing interaction that should have existed

Figure 4.2 Components and interactions of social-ecological systems in peri-urban waste water use

Figure 4.2 represents system components of a waste water resource and the resource users – the peri-urban farmers (who use this water to irrigate food crops). In this case the waste water was heavily contaminated with industrial and domestic effluent, with particularly high levels of toxic heavy metals. These heavy metals were present in edible portions of the crops being grown in these areas at levels which represented a serious threat to human health.

The components which are outside of the social-ecological system, shown within the dotted area of figure 4.2 are some of the components in this social-ecological system which is not formally recognised. As observed above , the other main components of the system, the public infrastructure in the form of rules and policies, and the public infrastructure providers in the form of government, government ministries and boards, which are responsible for implementing rules and policies, monitoring activities and dealing with any issues that arise, are invisible in this scenario. In other words, the institutions that act as the mediators between the resource and the resource users, facilitating as well as constraining its use and management (North 1990; Ostrom 1990), do not exist in relation to access to and control of waste water use. Some of the relevant institutions such as Water Policy, Environmental Policy, Agriculture Policy, Urban Planning, and providers such as the Water Pollution and Monitoring Board and other Departments do exist, but for other purposes (see table 4.2). For instance, the objectives of the institutions and providers is to provide a sustainable resource through planned water supply and equal distribution of clean water but this ignores peri-urban agriculture and waste-water use (Marshall *et al*. 2005). The invisible or missing systems also miss the key interactions which could have recognised risks associated with contaminated water use (table 4.2).

Table 4.2 Interactions between the components of social-ecological systems of waste water use and agriculture in India

Link	Interactions on the waste water use in agriculture: Case study of Varanasi, India
1. Between resource and resource users	Use of contaminated water for growing vegetables, which affects the soil and land of peri-urban communities and the health of peri-urban, urban and rural communities. But also provides benefits in terms of increased crop growth, and ensured water supply during times of scarcity.
2. Between resource users and public infrastructure providers	Limited standards for permissible levels of key toxic pollutants (e.g heavy metals) in irrigation water and very limited tested in soils and in fresh food crops. Limited recognition of peri-urban agriculture as a significant activity for income, employment and food provision to rapidly growing cities. Lack of recognition of link between environmental pollution and contaminated food.
3. Between public infrastructure providers and public infrastructure	Policies stressing quality of both surface and ground water; however, no direct link recognised between water quality and food safety. Lack of support and infrastructure.
4. Between public infrastructure and resource	International standards adopted for pollutant levels in water and crops which may not be appropriate and do not cover all pollutants present.
5. Between public infrastructure and resource dynamics	No official acknowledgement of waste water as a source for irrigation.
6. Between public infrastructure and resource users	No infrastructure to gauge the impact of waste water use, or to ensure that this valuable resource can be used in a safe and beneficial way.

Numerous problems arise from the invisibility of certain components that have severe impacts on the ecosystem and on human well-being, and affect long-term sustainability. These invisible components and their interactions result in informal transactions, i.e. use of contaminated waste water. This affects the social-ecological system beyond the boundaries of the water and peri-urban user systems (figure 4.2), extending to the urban and rural communities and presenting serious health threats. The peri-urban community is aware of these impacts, but there are neither any incentives or institutions to control the pollution at source, nor to provide alternative water sources, or ameliorate the adverse impacts of use of contaminated water. Marshall *et al*. (2005) observed high heavy metal content in the vegetables produced and in the soil used to grow them in. In the long run, this affects the social-ecological system of peri-urban, urban and rural communities. The institutions operating outside the boundary of the social-ecological system of waste-water use, manage, control and make decisions without any data on the interplay with the waste-water system. As suggested by Stirling (unpublished:1) policies made on '*science-based understanding of incomplete knowledge*', rooted in risk-based approaches, focus on interventions that control systems such that they maintain a 'balance', but neglect important strategies and characteristics related to governance for sustainable provision of water on the peri-urban fringe. The limited understanding about interactions taking place in a system often result in policy interventions that disrupt parts of the system, and affect the entire system in the long run. Similarly, when the problem of contaminated wastewater use was pointed out to ministers, there was a suggestion that production of vegetables in peri-urban areas should be banned. Such a response would clearly undermine the livelihoods of farmers who are dependent on the vegetable production, and would also have major implications for provision of nutritious fresh vegetables to the urban poor. It also fails to address a major and worsening contamination problem which will continue to impact on urban, rural and peri-urban populations, and fails to embrace opportunities for making the most of urban-rural synergies and working across sectors and disciplines to address the challenges that emerge.

The wastewater case is a good example of lack of recognition of the cross-sectoral linkages between water, agriculture and health in overall 'food-production systems' (Marshall *et al*. 2005). In figure 4.2, the interlinkages between water, agriculture and health mediated by contaminated water through farming and soil degradation transferred to large urban, peri-urban and rural areas are clearly visible; however, due to lack of institutional arrangements which can embrace these interlinkages, their impacts are overlooked. This is a highly undesirable state; external shocks, such as contaminated wastewater, can have an effect which remains hidden from the larger system.

In this case study, we observed that using a resilience framework we were able to identify how systems are interconnected; and shocks within a simple system might trigger change to larger systems, affecting systems across sectors such as agriculture, health and water. As systems are interconnected, policies for one system or one sector could have a knock-on effect on another systems. Using the issue of waste-water use, we could clearly identify what disturbs the systems and how different parts of the systems will be affected. This type of approach could potentially be utilised to understand and illustrate key interactions with a range of key stakeholders, as part of a process of determining new policy and management approaches to enhance sustainability.

4.3. Lessons from our peri-urban case studies

The dynamics of the peri-urban interface are not well understood, and there is a lack of analytical and management approaches to address key problems (Marshall *et al*. in progress). The resilience approach provides a basis for understanding, and illustrating to various stakeholder groups, which changes affect which groups of people and individuals, which in turn leads to the identification of a number of variables and options to cope with these changes. Understanding the strategies needed to cope with and adapt to change is directly related to the achievement of Sustainability.

Cities and urban populations will continue to grow resulting in ever bigger peri-urban fringes based on migrating populations (UN-Habitat 2001; UNFPA 2007); increasing urban poverty and food insecurity and problems related to meeting every day needs such as provision of drinking water, sanitation, health services, education, and managing urban waste and waste water are expected (UN- Habitat 2004). The total number of farmers worldwide using treated, partially treated and untreated wastewater for irrigation is estimated at 200 million, representing some 20 million hectares (Raschid-Sally and Jayakody 2008). Irrigation based on wastewater has advantages in that it contains nutrients which increase crop yields without the need for fertilizers; it also constitutes a method of sewage disposal and becomes an alternative water resource in areas where water is scarce (Feenstra *et al*. 2000). This implies that wastewater re-use has significant relevance for the broader policy agenda in terms of water conservation by substituting freshwater with wastewater and food security by increasing agricultural productivity on marginal and impoverished land. In the context of urban and peri-urban areas, wastewater is of global importance (Buechler *et al*. 2006). However, irrigation based on waste-water is a largely unregulated informal activity, mostly an illegal hidden transaction without the permission of the planning authorities. As has been illustrated here, this introduces particular stresses on the system components reducing the resilience of the larger system.

According to Buechler *et al*. (2006) ‘wastewater use…for agriculture is a cross-sectoral issue that requires a multi-sectoral and multi-actor approach to research and planning’ (Buechler *et al*. 2006). This implies that wastewater management is a dynamic and complex issue involving several levels, which requires diverse actors within diverse sectors and informed decision making and policy making for long-term Sustainability. Currently, decisions are made based on conventional measures, such as risk analysis and cost-benefit analysis, in which complex systems (see section 4.2) are broken down into simple, single and linear systems ‘*.described as reductive-aggregative approaches…resting on the decomposition of complex dynamic systems under appraisal, and their context*’ (Stirling *et al*. 2007:7). While trying to understand the complex system, in terms of simple and individual systems, decision makers can overlook important details such as the interaction between and within the system and the feedbacks which ‘*can restrict understanding and insight by ignoring key parameters and variables*’ (Stirling *et al*.

2007:7). This implies that classical appraisals, which break down the system, fail to account for dynamics and multiple states in deriving policy for management.

In our case study of contaminated waste-water use, the problem is not visible and the stress from the larger system is almost overlooked. Thus, decisions are made without any data and policies and management programmes formulated to control systems based on inadequate information. In such a context, resilience can highlight system parameters and attributes that might be affected during disturbances, or attributes that are important to the dynamics of systems.

Similarly, in the case of peri-urban case studies, the resilience approach has highlighted attributes that require attention, for instance, in the case study of water use, the tripartite agreement needs to incorporate the demands of dependent farmers and the expansion of water users to include urban domestic use and industrial needs. As the tripartite agreement has already brought changes in land use and social capital and to the livelihoods of dependent and semi-dependent farmers, any further shocks would have a very negative effect and increase aggression of dependent farmers towards the water selling farmers thus creating social conflict. Another important threat is over-exploitation of ground water, which is evident in the droughts and decline in the water table in Chennai. In the case of wastewater use, the invisibility of this threat needs to be recognised by the institutions that are present and to help in its management. Merely banning growing of vegetables is not a solution. Short-term solutions to interrelated management problems can often have long-term impacts on the sustainability of the dominant system (Berkes and Folke 1998). Lebel *et al*. (2006) stress that authorities often try to control systems to cope with small disturbances, such as flood or fire, by deploying different forms of property rights; in the long run this can lead to larger and more complex problems than the original disturbance.

In identifying potential disturbances and the parameters that are crucial for system organisation, resilience allows for multiple pathways to respond to changes through the ability to learn from change, and to strengthen key system attributes that will absorb the disturbance, while maintaining system functions by applying the available knowledge. One of the key elements in the resilience approach is understanding the parameter of structural changes for building resilience (Janssen *et al*. 2006). However, to understand the parameters important for the Sustainability of complex social-ecological systems, we need to go beyond a focus only on the resilience approach. This is because the dynamics of social-ecological systems occur in multiple states (Anderies *et al*. 2006) and to support the management process there is a need for cross-sectoral linkages (Gardner and Dekens 2007) and diverse institutions (Ostrom 2005). In this sense, it is helpful to unpack the concept of resilience to understand the dynamic system properties in the event of different disturbances occurring both internally and externally, such that governance systems could adapt to changes without losing the features and attributes of the system. The four main attributes of dynamic social-ecological systems that are important for Sustainability are durability, stability, robustness and resilience (Stirling 2007). Although unpacking the resilience concept into these specific attributes would help to understand the strength of a system, the challenge lies in operationalising them.

5. Way forward

Global environmental change has put more pressure than anticipated on the social and ecological systems experiencing continuous changes. This has exposed human beings with uncertainty, ambiguity and vulnerability to the impacts to the system. In that context, the challenge is not only how to build resilience of the social-ecological system, but also to identify for whom we are building this resilience. In line with these challenges, this paper aimed to explore how the use of the resilience approach can help to understand the complex dynamics of the peri-urban interface. Although the resilience framework helps us to understand the disturbances that impact systems at different levels, and how far the system can withstand the change, it does not go beyond this identification and illustration of they key interactions. As in social-ecological systems, the response to these system changes depends on power, politics and institutions. The resilience framework does not purport to understand issues of social justice, power, politics and culture as pointed by Hornborg. As suggested by other researchers, that strength of the resilience framework lies in the ability to combine with other frameworks of importance. Therefore, we suggest that in order to understand peri-urban Sustainability with issues of social justice, power and conflict we need to combine the resilience framework with other approaches such as political ecology approaches. In this context the resilience framework can be used to work with diverse stakeholders in creating dialogue over the appropriate adaptive governance in the context of Sustainability goals.

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