Watershed Development, Resilience and Livelihood Security: An Empirical Analysis

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Anuradha Phadtare, Neha Gupta, Vinit Raskar

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Abbreviations

CBO	Community Based Organisations
CPLR	Common Property Land Resources
DEM	Digital Elevation Model
DFID	Department for International Development
DLT	Drainage Line Treatment
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Federal Enterprise for International Cooperation)
GP	Gram Panchayat
GPS	Global Positioning System
GSDA	Groundwater Survey Development Agency
HPG	Humanitarian Policy Group
IGWDP	Indo-German Watershed Development Program
IMD	Indian Meteorological Department
KFW	Kreditanstalt für Wiederaufbau ("Reconstruction Credit Institute")
KVK	Krishi Vigyan Kendra
NABARD	National Bank for Agriculture and Rural Development
NDVI	Normalised Difference Vegetation Index
NGO	Non-Government Organisation
NREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
NTFP	Non Timber Forest Product
ODI	Overseas Development Institute
OECD	Organisation for Economic Co-operation and Development
RA	Resilience Alliance
RS/GIS	Remote Sensing/Geographic Information System
SES	Socio Ecological System
SHG	Self Help Group
SS	Sub- System
UN	United Nations
UPNRM	Umbrella Programme for Natural Resource Management
USAID	United States Agency for International Development
WATs	Water Absorption Trenches
WC	Watershed Committee
WOTR	Watershed Organisation Trust
WSD	Watershed Development

Glossary for Agro-Ecological Diversity (Local Names)

Local Name	English Name
Crops	
Bajri	Pearl millet/Bajra
Chana/Harbhara	Bengal gram
Chavli	Cow pea
Gur	Jaggery
Hulga	Horse gram
Jowar	Sorghum
Kodo	Kodo millet
Kutki	Little millet
Makka	Maize
Masur	Lentil
Matki	Moth beans
Matar	Green peas
Mohari	Mustard
Mung	Green gram
Nachani	Finger millet/Ragi
Rala	Italian millet
Til	Sesame/Gingelly seeds
Tur	Red gram
Urid	Black gram
Warai	French millet

Local Name	English Name
Forest Produce	
Babul	Gum Arabic tree
Ber	Indian plum
Bhilma	Bael fruit
Char	Piyal seeds
Haldu	Kadam/Haldu tree
Kachner	Fountain tree
Khair	Khair tree
Mahuva	Mahua tree
Neem	Neem tree
Sag	Teak
Sal	Sal tree
Sitaphal	Custard apple
Tendupatta	Beedi leaves
Umbar	Fig tree

Executive Summary

In recent times, watershed development is increasingly seen as an important strategy to mitigate weather-related risks and build resilience and adaptive capacities of communities to the impacts of climate variations and climate induced shocks such as drought. This study seeks to explore whether watershed development does contribute to building resilience and adaptive capacities of local communities and their ecosystems. It attempts to understand watershed development outcomes through the mirror of the resilience framework.

A key issue while framing the method of enquiry with regard to resilience enhancing potential of watershed development is whether and to what extent conventional impact assessment methods and indicators (of WSD) are relevant and could capture the resilience attributes and functions of the rehabilitated "Socio-Ecological Systems" (SESs) and what additions and modifications are required in the methodology so that resilience functions of such SESs can be identified and assessed?

The study draws on the conceptual methodological approaches such as 'Resilience of Socio-Ecological Systems' found in the resilience literature beginning with C.S.Holling and refined and applied by many researchers, authors as well as institutions like the Resilience Alliance (RA).

Resilience of an SES is fundamentally different from the resilience of an ecological or a social system in isolation. The SES, also referred to as a 'focal system', is linked to various subsystems at different scales.Interactions and outcomes within and across the scales of the focal system are not necessarily linear.

Resilience analysis often uses descriptive approach to comprehend the resilience as there are no clear metrics or indicators or a commonly agreed analytical framework to understand the properties of 'resilient SESs'. Understanding of resilience varies across time, space, the focal system under analysis and also in relation to stakeholders.

A composite framework with three inter-related components is proposed in the study. The first is a conceptual framework providing an overall architecture of the focal system in terms of subsystems and links, interactions and transformations across the subsystems and the drivers impacting the SES. The drivers include weather fluctuations, drought and watershed development (WSD) aimed at reducing sensitivity of the SES to weather variations and shocks.

The second is the analytical scheme which elaborates on the scale and the subsystem variables, both slow and fast. Resilience of an SES is often determined by how the slow variables are recognised and managed by the social system. Some of these variables are found in the set of conventional impact indicators. The variables used are a set of proxies and are seen as interlinked, influencing each other, the transformational traits and their rate of change.

The third part of the framework uses the properties or characteristics of resilient SESs.Transformational traits, their rate of change and links are assessed in relation to a seven-fold scheme of characteristics of socio-ecological resilience. Including resilience properties in the analysis helps understand resilience not only as a system property but also of a normative stand point.

Two focal systems (rehabilitated micro watersheds) from varying socio-cultural and agro-climatic conditions have been taken up for this study. Both the systems present distinct characteristics.

1. Socio-Ecological System (SES1): A watershed of Kinhola-Dawargoan in Maharashtra State is undertaken. It is a heterogeneous with highly stratified social system and is located in drought- prone, semi-arid agro-ecological zone.

2. Socio-Ecological System (SES2): A watershed of Kareli in Madhya Pradesh State is a homogenous

tribal community. With an assured rainfall the region has a forest-and-agro ecological sub-system. While socio-ecological interactions are very intensive in the former, the latter presents moderate interactions resulting in largely subsistence farming. These clear differentiators allow us to compare resilience characteristics across two distinct SESs.

In both the SESs, there is a significant change at varying magnitudes of the variables in the ecological sub-system, the forest and agro-ecological sub-system and the social and livelihood sub-systems and their properties as a result of the WSD driver and other factors. This has resulted in increased provisioning of ecosystem services such as water, productivity gains, income and livelihoods.The gains are 'significant' in normal times and visible to a great extent even after two successive drought years in SES1. In SES2, the changes in productivity and income are moderate, even though ecosystem provisions have improved significantly.

The social subsystem in SES1 pursues a very extractive and economically efficient interaction with the ecological subsystem resulting in reducing ecological diversity and reserves; while that of SES2 values diversity, subsistence-oriented production and low levels of extraction. From a normative perspective, resilience functions are found to be more inclusive, equitable and sustainable in SES2 as compared to that of SES1.

Transformational traits in both the SESs seen through the lens of 'resilience properties of socio-ecological systems reveal low resilience for the highly linked and higher growth SES1 in comparison to the moderately linked low growth SES2, even though, from a conventional point of view SES1, may be considered a successfully developed watershed.

This brings us to the important issue of managing resilience of SESs and the importance of facilitating adaptive management in SESs, acknowledging links and non-linear outcomes as a result of system interactions, and promoting institutional innovations, feedback loops, learning and innovation. Short period project-driven approaches ("project mode") have their limitations in facilitating adaptive responses to emerging concerns in an SES.

This study reveals that WSD can build adaptive capacities and resilience to a large extent; but 'the dominant package of practices' in WSD - technological, institutional and operational processes require revisiting and innovative changes. Lessons from adaptive co-management approaches to managing socio-ecological resilience could significantly contribute to making WSD an effective strategy for building adaptive capacities and resilience of communities.

Section 1: Conceptual and Methodological Issues in Assessing Resilience of Socio-Ecological Systems (SESs)

1.1 Introduction

In recent times, watershed development is increasingly seen as an important strategy to mitigate weather-related risks and counter the impacts of climate change. This study seeks to explore whether watershed development does contribute to building resilience and adaptive capacities of local communities and their ecosystems. It attempts to understand watershed development outcomes through the mirror of the resilience framework.

There is a large body of literature on conventional assessment of impacts and outcomes of watershed development (WSD) from the developmental perspective analysing its potential in augmenting the natural resource base and improving the socio-economic condition of the community. WSD as a resilience building strategy aiding adaptation to climate induced changes is a recent concern. It should be borne in mind that some of the flagship projects in watershed development were implemented in climatically variable and-ecologically fragile locations and focussed on creating sustainable livelihoods in the face of external shocks like drought and climate fluctuations. However watershed development in those contexts could be characterized as a set of 'business as usual measures' with focus on soil and water conservation measures that could enhance production and livelihood.

The focus of our study is intensely managed Socio-Ecological Systems (SESs). Such systems face climatic stresses in terms of drought, flash floods or hailstorms which impact the ecological services the systems can generate. These shocks affect the ecological, social and economic resilience of the larger system and its subsystems. Watershed development is undertaken in a socio-ecological landscape to counter the vulnerabilities arising out of climatic shocks, especially drought, and the larger environmental degradation. In our frame of analysis, we look at socio-ecological resilience as a result of the transformation attributed to this developmental intervention, that is, watershed development. These transformations are analysed using a socio-ecological resilience framework rather than a 'watershed impact' framework. Therefore, our analysis will attempt to identify and analyse the development-resilience links.

1.2 Concepts and Applications

Resilience is a generic concept and often used as a metaphor, meaning, the ability of a substance, system or people to bounce back to its previous state or functions quickly after a shock or disturbance. While the concept is applied in its generic sense in development and disaster mitigation[1], there is growing body of varied concepts and approaches

BOX 1: Definition

- Resilience refers to the capacity of a social-ecological system both to withstand perturbations from, for instance, climate or economic shocks, and to rebuild and renew itself afterwards (Stockholm Resilience Centre 2007).
- Resilience is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change (IPCC WG2 2007: 880).

1 The Disaster Risk Reduction perspective emphasizes mitigation and preparedness for shocks as an imperative utility for building resilience of communities (Alexander, 2013). Likewise developmental literature and policy documents emphasize the importance of enhancing resilience in the face of disasters or disturbances. For example, DFID uses the Asset Pentagon (5 capitals) of the Sustainable Livelihood Model for resilience enhancing activities. ODI's background paper (2012) approaches resilience enhancement through risk management across various sectors and policy areas. OECD stresses on resilience enhancement through various climate

Table 1: Resilience Typology and Characteristics

Resilience Concepts	Characteristics	Focus On	Context
Engineering resilience	Return time, efficiency	Recovery, constancy	Vicinity of a stable equilibrium
Ecological resilience	Buffer capacity, withstand shock, maintain function	Persistence, robustness	Multiple equilibria, stability landscapes
Social-ecological resilience	Interplay of disturbance and reorganization, sustaining and developing	Adaptive capacity, transformability, learning, innovation	Integrated system feedback, cross-scale dynamic interactions

Source: Folke (2006)

emerging from the resilience paradigm which are useful in analysing resilience of managed Socio-Ecological Systems (SES) such as watersheds. But it should be borne in mind that there isn't a widely accepted specific resilience framework and application of concepts and approaches which vary depending on the objectives of the analysis.[2]

While a distinction is made between engineering resilience and ecological resilience (also referred to as evolutionary resilience) in ecological sciences[3], social resilience and socio-ecological resilience has also become important concepts in recent times in analysing resilience of both social and ecological systems. Current discourse on resilience of SESs has repeatedly emphasised the need to link ecological processes with human practices (Levin *et al.*, 2001; Davoudi, Brooks and Mehmood, 2013). Empirical evidence around us suggest that most ecological systems are SESs, meaning, there are interactions at various levels and scales between ecology (nature) and society (institutions, economics, politics, culture and values and so on). These are not one-to-one interactions between various subsystems, but complex and non-linear interactions impacting the ecology and society at large. The present study focuses mainly on the characteristics or attributes of socio-ecological resilience as we are dealing with socio-ecological system such as rural watersheds.

Ecosystems could be considered resilient when they can absorb a shock without changing the system properties and functions; while social resilience refers to "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change" (Adger, 2000). Socio-ecological resilience is seen as "the capacity of ecosystems to sustain societal development and progress with essential ecosystem services" (Folke, Colding and Berkes, 2003). This definition brings into focus the normative concerns as resilience is linked to sustaining progress and development. However the type of progress that is pursued through development could be in conflict with resilience as well as sustainability in the absence of feedbacks and systems for adaptive management. Management can destroy or build resilience, depending on how the socio-ecological system organizes itself in response to management actions (Folke, 2002). Socio-ecological resilience reflects the capacity of the system to sustain and self-organize in the face of shocks and continue to maintain the same functions and structure without moving into undesirable domains. This study views resilience in this sense.

adaptation interventions especially in the field of sharing knowledge, technology, resources and so on. USAID policy and programme guidance is known as 'Building Resilience to Recurrent Crisis'. Most of these documents view resilience as a risk reduction strategy. Developmental sector (policies and programmes) mostly adhere to this view.

2 In a comprehensive review of the ecological resilience concept by UFZ Centre for Environmental Research, Leipzig-Halle, 'Ecological Resilience and its Relevance within a Theory of Sustainable Development', Fridolin Brand provides a detailed analysis of the meaning of the concept as proposed by various authors and applied in various contexts. The seven levels of meaning in which he analyses the concept include, 1) Original-ecological 2) Extended-ecological 3) Ecological-systemic 4) Operational 5) Sociological 6) Socio- ecological and 7) Explicitly-normative. The centre of his argument is that most of the definitions of the concept are descriptive in nature and do not present the concept as a normative frame of reference. Other sources are the works by Resilience Alliance (RA) and a comprehensive review of the 'resilience' concepts and application by the Rockefeller Foundation, to suggest a few.

3 The distinction initially made by Holding (1996) considers engineering resilience as the capacity or ability of the system to return to an equilibrium or steady state after a disturbance and ecological resilience is defined as the 'the magnitude of the disturbance that can be absorbed before the system changes its structure and functions'. While the former is concerned about the 'bounce back' property, ecological resilience focuses on 'the ability to persist and the ability to adapt' (Adger, 2003). Elaborating on the distinction between these two types of resilience, Davoudi (2012) cites that the main difference is that ecological resilience rejects the existence of a single stable equilibrium and instead, acknowledges the existence of multiple equilibria and the possibility of systems to flip into alternative stability domains.

This study proposes to apply the socio-ecological resilience approach because the human domain and the biophysical domain are interdependent (Walker and Salt 2006) having reciprocal feedbacks which enable us to view the properties, processes and functions of the system as a co-dependent entity. This describes also the characteristics of a watershed production landscape. A socio-ecological approach to resilience helps in understanding the interactions and linkages among various subsystems and their variables that constitute the larger Socio-Ecological System (SES). The interactions among these sub-systems most often are non-linear and can result in multiple outcomes. Impacts of human interventions, politics or policies on one sub system or on its components would have intended or unintended impacts on others which would either enhance or retard the resilience of the overall system.

A socio-ecological approach also helps in better understanding questions like 'resilience to what', 'resilience of what' and besides, the issue of 'resilience of whom'. Are we looking at the resilience of watershed ecology or the resilience of the watershed community or the resilience of the watershed production and agricultural sub-system or all of these as an interlinked system? While sensitivity to disturbances or disasters ('resilience to what') varies across the sub-systems it may also vary among different stakeholders such as agriculturalists, pastoral groups, women, landless and so on. In the social context, we cannot consider resilience without paying attention to issues of justice and fairness in terms of both the procedures for decision making and the distribution of burdens and benefits (Davoudi 2012).

1.3 Operationalising and Measuring[4] Socio-Ecological Resilience

Resilience literature provides various attributes or resilience properties of an SES. Drawing mainly from the RA's work book "Assessing Resilience in SES" (2010), "Resilience Thinking: Sustaining

Table 2: Characteristics/Properties of a Resilient SES

Diversity: Variety in the number of species, people and institutions that exist in a socio-ecological system. It includes both functional and response diversity. Lack of diversity limits options while increasing efficiency may lead to reduced diversity.
Tightness of feedback: How quickly the consequences of a change in one part is felt and responded by other parts determines resilience. The longer the feedback time, the higher the chances of crossing a threshold without being detected.
Openness: There is no optimal degree of openness and either of the extremes can reduce resilience. If the components or sub-systems of the larger system are closely linked, the impact of the shock would run through the entire system. This is also true when the focal system is too open.
Reserves: In general, more reserves mean greater resilience; but the trend is often a loss of reserves, both ecological (e.g., habitat patches, seed banks) and social (memory and local knowledge).
Modularity: Relates to the manner in which the components that make up a system are linked. A fully connected system can rapidly transmit any shock (a disease, a bad management practice, etc.) through the whole system. In a system with tightly interacting sub-components that are loosely connected to each other (i.e., a modular system), parts of the system are able to reorganize in response to changes elsewhere in the system in time to avoid disaster.
Social Capital and Overlapping Governance: Refers to the trust, networks and leadership of a community that helps in managing, adapting and keeping the system from flipping into undesirable regimes. Governance should include overlap in institutions (institutional redundancy), multiplicity of defined property rights and vertical and horizontal linkages among various institutions of informal and formal kinds.
Ecosystem Services: These include provisioning, regulating, supporting, cultural and spiritual services that ecosystems provide. These are valued by a social system and are essential for livelihood, development, ecosystem sustainability, etc.

4 Even though resilience emerged as a popular conceptual and descriptive system to analyse socio-ecological systems, it still lacks a commonly agreed framework or set of indicators that would assist in assessing a resilient SES. One area in which resilience theory is critically underdeveloped is in metrics. This is difficult to operationalize because of its abstract and multi-dimensional nature (Bergamini and Blasiak, 2013). At the same time, there are also warnings about the dangers when ecological methods are applied to soco-ecological systems and any specific measure chosen is based on availability of data rather than any normative concern. (Levine *et al.* 2012). One of the major challenges of measuring resilience is that of identifying appropriate variables or attributes as they vary according to context and preferences of social actors.

Ecosystems and People in a Changing World" (Walker and Salt, 2006) and various literatures[5], we posit the following as general characteristics of a resilient SES.These seven characteristics are considered as the operational reference or schema for analysing resilience of watershed SESs in the present study. (Refer Table 2.)

1.4 Watersheds as SESs

Micro watersheds, the focal system and the unit of analysis in the study, are intensely managed SESs[6]. It is a hydrological-linked landscape continuously influenced, impacted and altered by human interaction. Humans influence its processes and functions and manipulate ecosystem services to ensure socio-economic well-being. At the same time, the extent of ecosystem services the biophysical regime could support limits human actions unless facilitated by technology, knowledge and institutions.

A watershed consists of various sub-systems such as watershed ecology, agricultural subsystem, social, institutional and livelihood sub-systems, etc. While ecosystem variables (mostly slow variables) like soil, land use, hydrology, etc., influence socio-economic variables (mostly fast variables) such as production, income, access to resources, livelihoods, etc.)[7], the relationship is not necessarily one-to-one or linear in nature. They are mediated and impacted by human actions, technology, power dynamics, institutional mechanisms, political economy, and governance structures and so on. As in any other SES, the interaction across sub-systems and their variables is dialectical and mutually impacting.

Spatial and temporal scales critically impact the watershed SES and its resilience. Since the landscape at a spatial scale is hydrological-linked, the focal SES (say a micro watershed of a few hundred hectares) is not an autonomous unit. It is impacted by higher scales as a watershed, mega-watershed, sub basin, etc., and lower scales such asland use patches or a farm unit (households). The processes and functions of the regimes at these scales impact resilience at the focal system, the micro watershed unit in this case.

At temporal scales, the resilience and stability properties at a specific point of time may be at the expense of what is going to unfold in the future, for example, over-extraction of ground water may give the impression of increased resilience in the present to short term, but result in reduced resilience and conversely, increased vulnerability, in the future. This is true when the ecosystem resources and services are altered and mobilised for social and livelihood resilience. Ecosystem resilience of an SES at a specific time period can be gained at the expense of a succeeding period; or ecosystem resilience at a particular scale can be subsidized by the broader scale (Carpenter *et al.* 2001, Folke *et al.* 2002). In analysing watershed development and resilience, this issue becomes crucial as it underscores the importance of understanding issues of equity and sustainability.

1.5 Watershed Development and Resilience

Watershed Development (WSD) is a multi-sectoral intervention aimed at enhancing the potential of ecosystem resources and the socio-economic situation of the community in a specific landscape unit. WSD is implemented in rain-fed areas (often in degraded landscapes) at smaller scales of micro

5 Besides Walker and Salt and Resilience Alliance (2010), the study also adopted concepts from the following sources: Walker, and Gunderson, and Kinzig (2006), Twigg (2009), Martin-Breen and Anderies (2011), DFID (2011) Bergamini, Blasiak, *et al.* (2013), Binder, Hinkel, *et al.* (2013), Ifejika Speranza, C. Wiesmann and Rist, S. (2014) etc. However we should keep in mind that there are no specific set of resilience characteristics/properties or indicators of resilience and it varies from author to author as well as the context and type of SES under investigation. We have drawn the above list based on commonly found characteristics across a large number of sources and situations which are relevant for a watershed SES.

6 Socio-Ecological Systems are neither purely ecological nor purely social systems but systems which are constantly interacting with each other, influencing and altering the behavior of both and introducing changes in both structure and functions of the respective social or ecological sub-systems. Rural watersheds are the best examples of SESs and watershed development impacts the interactions across these sub-systems.

7 This does not mean all fast variables fall in the social system realm or slow variables in the ecosystem domain. The property regime, tenure rights, values, culture, etc., which fall in the social sub-systems are also slow changing variables (RA2010). Slow variables determine the state of the regime (such as a watershed) and its performance on various functions including provisioning of ecosystem resources. Ecosystem resilience is impacted by the interactions of slow and fast variables. Together they are called "state variables" (variables of the system state). They are dynamic and alter as a result of external drivers such as rainfall, market failures etc.

watersheds units[8]. The interventions include a series of mechanical, vegetative and agronomic measures on the landscape to conserve biophysical resources; community organization to enhance social capital and networks; and participatory strategies to enhance community ownership of the intervention.

The major question that arises is whether such an intervention can be viewed as a strategy to build and manage resilience of the watershed SES?

WSD has the potential to reduce risks associated with rain-fed agricultural production system. Various studies and evaluations of WSD highlight these by measuring changes on various biophysical and socio-economic indicators (Kerr, *et al.* 2000, Samuel, Joy, *et al.* 2006, ICRISAT 2008, Shah, Samuel and Joy 2011, Planning Commission 2007, MoRD 2006). Thus, WSD could be seen as a disaster risk reduction strategy leading to more resilient systems. Thus, it would be a promising area to assess whether the current set of practices clubbed under WSD factor in resilience outcomes in its planning and implementation. Can the conventional measures aimed at enhancing resource conservation and capacities of the community (the "business as usual" measures in WSD) lead to socio-ecological resilience of a highly managed SES, such as a watershed?

Resilience literature looks at resilience building (and managing) in complex SESs as a combination of self-organization and adaptive co-management which includes resilience-based stewardship (RA 2010). They highlight the perils of steady state or command and control management of resources with its emphasis on 'efficiency' (Holling and Meffe, 1996). In contrast to this, they propose adaptive management with its emphasis on increasing the adaptive capacity of the SES so that it could respond to and facilitate change (Peterson 2002). RA provides a set of strategies to approach resilience-based stewardship of SESs which includes "fostering biological, economic and cultural diversity; a mix of stabilizing feedbacks and creative renewals; social learning through experimentation and innovation and adaptive governance to changing conditions" with each of the four strategies having a number of steps (RA 2010, p. 47). Whether watershed development and its outcomes lead to adaptive management or steady state management would be an interesting issue to be looked into.

The goals of an ecosystem resilience analysis are (1) to prevent a socio-ecological system from moving into undesirable 'basins of attraction' in the face of external stresses and (2) to nurture and preserve the elements that enable the system to renew and reorganize itself following a massive change (Walker *et al.* 2002). Whether WSD has the potential of achieving these goals is the crucial question. Thus, this study has normative concerns also. This aspect is what distinguishes a conventional impact analysis of WSD from a socio-ecological resilience analysis.

8 There is no arbitrary recommendation on scale in watershed development literature, practice or policies. Different programmes and agencies have their own unit for intervention depending on various factors such as availability of resources, ease of management and governance, matching the scale with administrative units such as village etc. However there is a growing realization that a large spatial scale would be appropriate to optimize water resource management, livelihood linkages and so on. However, up scaling (vertical sense of the term, moving up from micro watersheds to watersheds to sub basins) is found to be a challenge (Kerr 2007). The issue of scale is pertinent not just from the hydrological aspects but also on issues related to distribution of cost and benefits.

Section 2: Study Framework and Data Sources

2.1 Framework for analysis of SES

There is no uniform or singular framework to assess the resilience of an SES. A set of descriptive methods are often used (Walker and Salt 2006, RA 2010). We propose a composite framework which includes a conceptual framework (Fig. 1), an analytical scheme (Fig. 2) and a seven-fold operational reference or schema of 'resilience properties of an SES' (ref. Table 2) for the purpose of the present study.

While the Conceptual Framework (Fig. 1) provides the overall architecture of the SES in terms of various interacting subsystems (watershed ecology, society, livelihood, production system, etc.), drivers (climate variability and WSD) and resilience traits as a result of the relation and interaction across various subsystems, the analytical framework (Fig. 2) providesthe scales and variables employed in the study that helps in understanding and analysing resilience traits of the subsystem. Resilience of the two watershed SESs under study is assessed

Fig. 1: Conceptual Framework

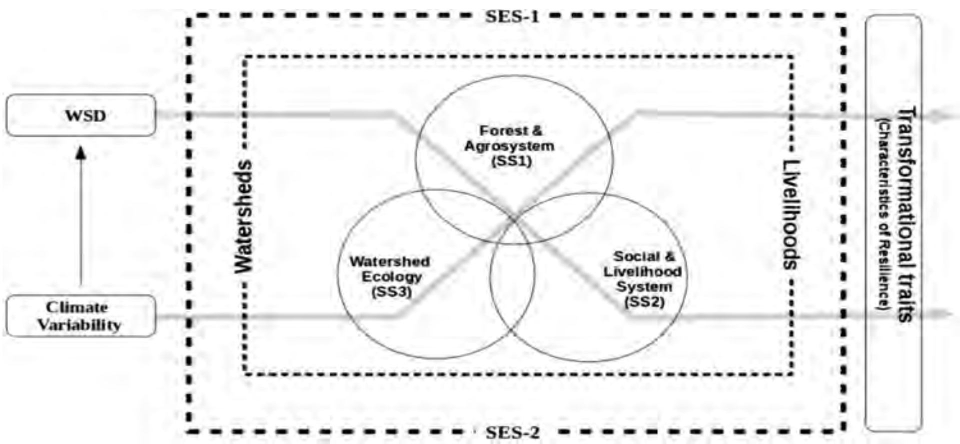
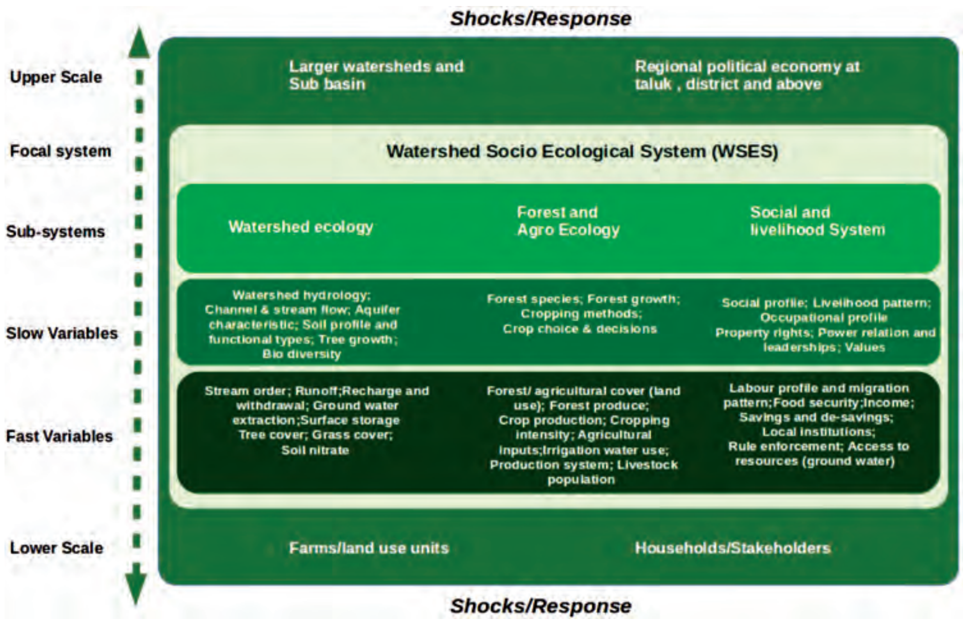


Fig. 2: Analytical Framework



by measuring changes in the variables across a specific timescale and comparing those changes with the seven-fold conceptual schema of resilient SES. When looking at resilience of a linked SES, the opportunity at hand is to establish the relations between these variables that distinctly operate for the overall functioning of the system (Carpenter, Walker, Anderies and Abel, 2001; Davoudi *et al.*, 2012; Walker, Gunderson and Kinzig, 2006).

The conceptual framework comprising key drivers' nested sub-systems and transformational traits guides the analysis in the following chapters and together with the analytical framework comprising the scales and variables, provides insights into the overall linkage and functioning of the focal system under investigation. This composite framework is applied to both the SESs, setting the ground for a comparative analysis.

2.2 The Focal System

Two distinct focal systems are selected for the study. Both have WSD as a driver and are located in different agro-climatic and socio-economic contexts. SES1 (the Kinhola-Dawargaon Watershed) located in a drought-prone region is characterized by weather variations and impactedby drought periodically. SES2 (Kareli) is located in an assured rainfall region. Weather variations are observed in SES2 but are not as severe as in case of the former.

Both the SESs have distinct socio-economic characteristics. As we see in the description in the following sections, the village of Kinhola-Dawargaon (SES1) predominantly conforms to market-driven farming system which significantly contrasts with the largely subsistence farming and forest based system predominant in Kareli (SES2). Other differential attributes between the focal systems continue to emerge from the social structure, land use patterns, socio-economic nature of households, geo-hydrology, water resource and so on.

2.3 Drivers, Variables and Scale

The key driver in the two SESs under study is watershed development which is seen as a techno-institutional response to the other driver, namely, climate variability; the understanding is – while climate variability induces recurring disturbance, WSD builds responsiveness of the SESs to such shocks. In times of drought and rainfall variability, changes in availability of water (both ground and surface) impact the SESs which results in severe shock or disturbances to the system. The WSD interventions are aimed at building responsiveness, sustainability and participatory management of resources for equitable distribution of benefits. The impacts of the drivers on the focal systems are at the core of our analysis.

WSD as a driver tries to alter some of the hydrological processes such as runoff and land use patterns. It also influences the community processes through formation of project based institutions and regulation mechanisms. WSD creates impacts, but often, those impacts could be at the expense of environmental sustainability, if governance mechanisms are not in place. This would be a crucial point of analysis when we look at watershed development from the perspective of the resilience framework[9].

Table 3: Description of the SESs

The SES	Country	State	Natural/social Region	District	Block/ Taluka	Agro-climatic location (NARP)	Latitude	Longitude
Kihnola-Dawargaon* (SES1)	India	Maharashtra	Marathwada	Jalna	Badnapur	Central Maharashtra Plateau Zone (semi arid)	20° 1′1.31″N	75°41′41.87″E
Kareli (SES2)	India	Madhya Pradesh	Narmada Sone Valley	Jabalpur	Jabalpur	Central Narmada Valley Zone	22°59′57.14″N	79°46′27.53″E

* Kinhola-Dawargaon are two different villages that come under a single watershed catchment and is considered as a single project

9 A note of caution is in order: the time frame (temporal scale) involved in our assessment of certain components of the sub-systems is limited to the period before the WSD intervention and at the time of the study, a period of about 12 years only.

2.4 Disabling Drivers, Rainfall Variations and Droughts

The average annual rainfall in SES1 is around 725mm (28-29 inches) and more than 80% of the rainfall is received during June-September. The region has experienced severe droughts[10] periodically and deficient rainfall in eight years since 1998, with declared drought condition in 2004-05 and successively in 2011 and 2012. Long term gridded data on rainfall during 1971-2013 shows that there was deficient rainfall during 23 years. Not only drought, the rainfall is highly variable with regard to onset of monsoons and also variation in rainy days, rainfall intensity and dry spells.

Table 4: Rainfall Variation in SES1

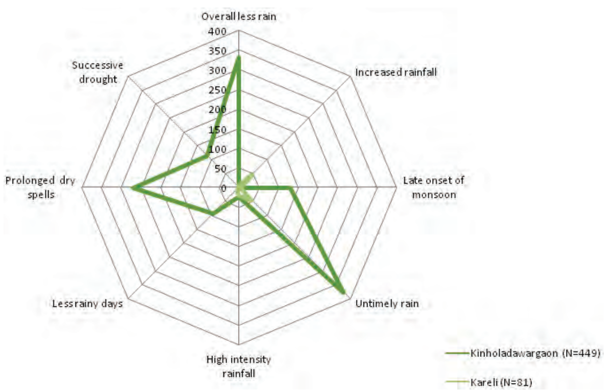
Year	Standard Deviation (mm)	Coefficient of Variation
1971-1981	205.04	30.11
1981-1991	192.04	26.74
1991-2001	239.69	33.39
2001-2011	249.85	34.70
1971-2013	215.89	30.70

Source: IMD gridded data

Recent trends show considerable decrease in rainfall in June which affects agricultural operations and the cropping cycle.

The SES experienced two successive droughts in 2011 and 2012. The recorded rainfall in the nearby station of Badnapur was 472 mm in 2011 and only 337.6 mm in 2012 (another rain gauge station nearby, at Jalna KVK, records only 200 mm in 2012 denoting a significant spatial variation). This was less than 50% of the normal rain. Villagers compare this drought to that of 1972[11]. However, they say that while there was water for domestic and livestock needs during 1971-72, they had a food grain shortage. During the 2011-2012 drought, it was the reverse: no water for livestock and humans but availability of food grains. This paradox needs to be viewed from the perspective of the political economy of water, especially with regard to ground water extraction and ground water-driven development.

In comparison to this, SES2 has not experienced severe droughts even though deficient rainfall and weather variations are reported in the area. The gridded data for 1971-2012 shows an average rainfall of 1163.4 mm (long term average for the area is 1162 mm) and a coefficient of variation of 22.34%. During the three years, the rainfall deficiency crossed the critical mark of above 25%. Heavy winter rains are reported by the community affecting crops and livelihoods. The late onset of monsoon and deficient rainfall since the last few years in June is highlighted in the District Agriculture Contingency Plan of Jabalpur District where SES2 is located.



Graph 1: Community Perception of Changes in Rainfall Pattern
Source: Study Census Survey of Households

Table 5: Rainfall Variations in the Month of June (SES1)

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Normal
Amount (mm)	**25**	25	179	185	48	72	48.9	42	34.3	131.2	163.7

Source: Mahagri portal: rainfall data

10 Indian Meteorological Department defines drought in any area as when the rainfall deficiency in that area is 26 per cent or more from its long-term average.

11 This drought was the impetus and reason for the launching the Employment Guarantee Act in the State, a pioneer programme in the country and the precursor to the now famous national programme called Mahatma Gandhi Rural Employment Guarantee Act (MGNREGS).

Table 6: Physical and Financial Details of WSD

Watershed Measures	SES1 (Kinhola-Dawargaon) Physical Work	Financial Expenses (RS)©	SES2 (Kareli) Physical Work	Financial Expenses
Work on landscape				
Afforestation work and horticulture development	47.63 ha and 160.43 ha	1.152	-	-
Crop land development	815.98 ha	3.390	244 ha	1.692
Work on drainage network				
Minor work such as stone dams etc.	23 structures	0.0594	-	-
Major works (cement and earthen dams)	11[13] structures	1.316	6 structures	0.367
Trainings and exposures	26 programmes	0.091	18 programmes	0.114
Women's development activities	90 beneficiaries	0.165	57 beneficiaries	0.120
Other works (irrigation development such as well construction and pipeline laying, demonstration of crops etc.)	-	-	19 wells, 39 crop demonstration plots, 1 group sprinkler irrigation set etc.	0.753
Total		**6.173**		**3.058**

© Financial expenses in millions of Indian Rupees *(Source: Project Completion Reports prepared by facilitating NGOs)*

Late rains, long dry spells, fluctuations and high intensity rainfall is also noted by the community in both the locations particularly so in the case of SES1, as indicated in Graph 1.

2.5 Enabling Drivers: Watershed Development

While rainfall variations and droughts are drivers in terms of shocks to the SES, WSD is posited as a strategy to reduce its impact on the SES. Initially viewed mainly as an environmental service intervention (catchment stabilization objective) with a focus on the ecological subsystem, it has moved into addressing the concerns of the socio-ecological system by bringing ecosystem services and human welfare considerations under the ambit of watershed development. Both our SESs had watershed intervention with slightly different objectives and under different modes of intervention.

The Indo-German Watershed Development Program (IGWDP) was implemented in SES1, while a small scale programme known as "Wasundhara Watershed Development" was implemented in SES2[12]. Both the projects were externally financed. While WOTR was the direct facilitator and implementing agency along with the village organizations and the community in the latter, it was the capacity building and fund channelizing agency in the former, along with NABARD, a local NGO and local community organizations.

As part of watershed development, drawing on a detailed participatory plan, the activities undertaken in the respective SESs are described in Table 6:

In order to understand the coverage of the work at individual farm and household level, we elicited responses of the villagers on various measures undertaken under the program. At the individual farm level, the most common conservation measure is bunds made on the farm borders (or within) to facilitate in-situ soil water conservation.

12 The IGWDP is a major watershed development project in the country and a bilateral intervention where WOTR, NABARD, implementing NGOs and CBOs worked collaboratively, supported by various government agencies. It is considered a very successful project in terms of its geographical spread, impact and contribution to policy and similar national programmatic interventions. The focus was on participatory soil and water conservation measures together with production enhancement. Wasundhara was an integrative programme developed and implemented by WOTR with a focus on livelihood promotion, poverty reduction and giving effective representation to marginalised groups within a watershed development context. Thus, both the schemes could be called two different modes even though the basic tenets of soil and water conservation were followed in both the contexts.

13 In addition to this there are 10 masonry water harvesting structures (check dams) built by the government as observed during the transact walk. Public investments on WSD works is very limited in SES2.

82% of the land holders from SES1 and almost all farmers from SES2 report construction of farm bunds on their lands. 22% of the farmers report various water harvesting structures near to their lands which benefit them.

On common land resources, 92% farmers report undertaking of contour trenching in SES1 while 72% report the same in SES2. Afforestation and plantation is reported by 71% in SES1. Gully control measures are reported by 65% and 63% respectively in both the SES1 and SES2. However we should note that most of these measures require maintenance and repair which is found either lacking or inadequate.

2.6 Scale

Scale helps in setting the spatial and temporal boundaries of the focal system (micro watersheds) and establishing its connectedness to upper and lower scales. The connectedness and influence across various scales impacts the resilience traits of the focal system. Determining the scale based on the existing state of the system is a critical step to understanding resilience as an emergent property, as the SES comprises of linked or nested sub-systems (Walker and Holling, 2004).

The focal scale for our study is set at the micro-watershed level (given that this is the scale of the watershed intervention) and observed at three timeframes – before WSD, after WSD (present) and during the drought period[14]. While the lower scales at farm, farming households and land use patches are analysed in detail, the upper scale (high order watersheds, sub-basin etc.) is given limited attention as there is paucity of data at these levels.

14 Applicable to SES1 as it is located in the drought-prone region and experiences periodic droughts as compared to SES2 which is in the assured rainfall region.

2.7 Variables

The changes in each of the sub-systems are associated to key variables shown in Fig. 2. The influence of variables on each other is at the core of the framework to draw insights into the various aspects of systemic resilience. Since the changes in the state of the variables are not even, a distinction (between slow and fast variables) is made on the basis of the rate of change a variable undergoes and the duration the properties of the variable remain unchanged. For instance, the changes occurring in property regimes (for example ownership of ground water is related to ownership of land) are relatively slow and the characteristics remain stable for a longer duration when compared to fast variables, such as extraction of ground water. The variables for each of the SESs are categorised as per the sub-systems, which enables one to understand the transformations occurring in each of the sub-systems. The linkages between the fast and slow variables are an important aspect of the analysis, which also determine the magnitude of the transformation. The dynamic interaction of the variables with the upper and lower scales of the focal system is viewed as a continuation of the linkages, with shocks and responses traversing across scales. Insights into the resilience aspects of the focal systems are drawn from the transformational traits (outcomes) observed from the analysis.

The transformational traits (outcomes of crucial variables) across the systems and sub-systems are analysed with reference to the seven-fold schema of resilience properties of SESs described earlier in section 1.3.

2.8 Data Sources

Primary socio-economic data through household surveys, remote sense spatial data and extensive secondary data were employed for the study. Focussed Group Discussions were conducted to gain community insights.

While extensive data is collected for the focal system and the scale lower at farm and household level on various slow and fast changing variables, data on upper scale is limited to secondary information that is in the public domain and by drawing on

Table 7: Details of Household Surveys and Remote Sensing Image

Tools[15]	Universe/Sample size	
	Kinhola-Dawargaon	Kareli
Census survey of all households	452	92
Detailed Household Interviews[16]	64	41

Details of Remote Sensing Image

Sr.No.	Satellite	Sensor	Date	Spatial Resolution
Images for Jalna				
1	Landsat 7	ETM+	20 Oct 2002	30 m
2	IRS P6	LISS 3	30 Dec 2012	23.5 m
3	IRS R2	LISS 3	20 Dec 2013	23.5 m
Images for Jabalpur				
1	Landsat 7	ETM+	29 Dec 2002	30 m
2	IRS P6	LISS 3	15 Dec 2011	23.5 m
3	IRS R2	LISS 3	16 Dec 2013	23.5 m

our knowledge gained through working in the region for many years. While primary data on upper spatial scale is limited, data on the temporal scale is limited to 'before' and 'after' watershed[17] and during the drought (for SES1).

15 Primary socio-economic and resilience data was collected using three tools: a survey of all households (hence census survey not sample survey) in the focal systems on a few crucial variables followed by a detailed interview at household level using a stratified random sampling covering a large number of variables; this was supported by focussed group discussions with stakeholders and transact walk of the watershed landscape. The data was analysed using SPSS and excel programmes.

16 While all available households were covered in the focal watersheds, sample surveys of 40 households each from two neighbouring villages namely Dhabadi and Chirapondi located near SES1 and SES2 respectively were conducted to gain insights into villages where watershed interventions have not been undertaken. This helps in attributing links to watershed development-induced changes.

17 This could be considered as a limitation of the study as changes in slow variables do occur over a longer time and require comparable data over many years.

Section 3: Social and Ecological Characteristics of the Focal System

The focal systems (SES1 and SES2) are characterised by two distinct typologies. Kinhola-Dawargaon (SES1) is an intensely managed socio-ecological system as compared to Kareli (SES2). Agriculture is the dominant land use system in SES1. Groundwater is the most crucial and valued ecological service and the agricultural sub-system is closely connected and influenced by the availability and extraction of ground water. In comparison, Kareli (SES2) is a moderately managed landscape with agriculture, forest and other land use systems. Agriculture is relatively autonomous from ground water extraction here as SES2 has different water sources such as ground water, water from the local streams and seepage water from forests which helps the subsistence farming predominantly found here. The former is an intensive production and resource use landscape while the latter is a moderate and subsistence-based land use system. These differences in topologies will have an impact on the resilience traits of the SESs. From the adaptive cycle metaphor or perspective, we could say that SES1 is in the forward loop of conservation stage (k) while the other is in the growth stage (r)[18].

3.1 Ecological Characteristics

The agro-climatic, geo-hydrological and other ecological features also vary. While SES1 is located in the Central Maharashtra Semi-arid Plateau having a rainfall of around 700 mm, SES2 is in the Central Narmada Valley Zone with above 1150 mm rainfall. Geologically, the former is in the Deccan basalt with shallow aquifers that exhibit erratic variations in the ability to store and transmit groundwater within small distances. The latter is located in the Upper Plains of Narmada river basin which is characterized by a mix of soft rocks from alluvial deposits having primary inter-granular porosity and permeability with promising formation for ground water development (Refer table 8).

3.2 Social System and Livelihood System

The social landscapes consist of various castes in SES1. Two dominant agricultural castes of Maharashtra, namely, the Marathas and Malis, constitute 2/3rd of the households, while Dalits (mainly neo Buddhist) form around 20% of the households. The rest are resettled nomadic tribes and other castes. The dominance of the agricultural community impacts the behaviours of the agro-ecological sub-system. While the social and political life is dominated by these two, there are undercurrents of tensions between various sections, especially the Dalits and the Maratha community. This is very much a characteristic of that region and has historical roots.

The project leadership was mainly controlled by these two sections: the Mali community in Dawargaon and Marathas in Kinhola. The Dalits and others were generally excluded from the decision making processes. In comparison to this, Kareli is a Tribal (Gond) village and there are only 4 non-tribal families. Gonds are traditionally forest dwellers and a close-knit community. Socio-cultural uniformity is a strong factor in SES2. Nobody in the village felt that they were excluded or not consulted.

18 Ecological resilience literature suggests that systems move in an adaptive cycle from exploitation (r phase) characterized by growth and emergence of pioneers where system components are weakly connected ; conservation (k) phase characterized by accumulation and specialization with strong links across components of the system; , creative destruction (omega - Ω) where systems resilience breakdown due to reinforcing interactions and); renewal (alpha - α) where new players are sorted out by the system that helps the emergence of the new cycle starting with exploitation (r). While the transformation from growth to conservation can be gradual and slow with increasing connectedness, the creative destruction and reorganization is swift and sudden triggered by threshold levels or by external stimuli. However, this pattern does not necessarily reflect a cycle, and alternative sequences of the phase transitions have been identified. This is especially true for SES as human intentions and capabilities do influence the structure and functioning of the system to conservation (k phase) to release (Ω phase) and reorganizations (α phase). (Holling and Gunderson 2002, Fridolin Brand 2005.

Table 8: Ecological and Biophysical features

Indicators	SES1 (Kinhola-Dawargaon)	SES2 (Kareli)
Area (ha)	1497	500
Rainfall (annual average in mille meters)	725	1162
Geo-hydrology	Deccan trap basalt, shallow aquifers, localised variations in GW	Soft rock of Alluvium deposit and partly Deccan Basalt, promising formation for GW
Soils	Mainly shallow and medium black, poor organic content, 20-90 cm depth, mainly alkaline	Brown and shallow black soil, 30-120 cm depth, good organic content
Major land use		
Private land (% to total)	90.73	42.44
Forest & community land (% to total)	9.27	57.66
Cultivated land (% to private land)	87.36	73.5
Seasonally irrigated (% of cultivated)	62.8	48.3
Perennially irrigated (% of cultivated)	2.9	0.5
Rain-fed land (% to total cultivated land)	33.33	51.2
Permanent fallow (% to private land)	7.27	17.65
Encroached (% of forest and community land)	8	16
Water Resource	**Ground water**	**Ground water and surface water (stream and spring)**
Open Wells[19]	272	37
Bore wells	16	0
% of framing HH using GW	82 (319 of 388)	57 (43 0f 75)
No. of HH using surface water for irrigation	1	30

Source: Study census survey of HHs, Project reports and Revenue Records

Agriculture is the dominant primary occupation in both the SESs. The secondary source of livelihood is varied in SES2 with reliance on forest produce and seasonal migration contributing mainly to the cash requirements, as agriculture is subsistence oriented. All households have a second source of income in SES2 while over one third of households in SES1 have agriculture as their only livelihood source. In recent times, households are broad basing their portfolio and the better-off are investing in education and other businesses in SES1. This, they say, is the only way out, given the shrinking land holdings and declining revenues from agriculture. These avenues are limited for the households in SES2 who augment their income through short-term migration and through collection of minor forest produce.

Land ownership is skewed; landless households are 14% in SES1 and 17.5% in SES2. While two third of farming households are small and marginal in the former, they constitute just above half of the farming households in the latter. Inequality of assets affects resilience at the household level. The Gini coefficient (denoting inequality) for landholding is 0.51 and 0.56 in SES1 and SES2 respectively. Land ownership is linked to the dominant castes in SES1: 76% of the private land is owned by the Maratha and Mali communities, the two dominant sections in SES1. Such socio-cultural factors are closely linked to the resilience traits at household levels. Various other assets such as ownership of vehicles, tractors, consumer durables and so on are also unequally distributed.

Communication assets such as mobiles, motorbikes and television sets show an impressive growth in SES1 and to some extent in SES2. Infrastructural facilities for communication are good in SES1 while, it is very poor in SES2. Communication is key to managing resilience – communication within the community and also with the outside world (vertical and horizontal communication) impacts resilience management. In this regard, two

19 The size of the wells and hence the investments vary considerably in the SESs. While the depth of wells range between 40 and 75 feet in SES1, they are shallow and the depth of well is around 15-20 feet in SES2. The cost of construction goes above Rs. 1.5 lakhs (due to hard rock strata) in the former; it is around Rs. 25,000-Rs. 30,000 in the other. Of the total 37 wells in SES2, 19 are constructed by the project while another 13 are through government subsidy and only 5 wells are constructed by private investments. In comparison to this, all wells are privately developed in SES1. Only around 15 wells in SES2 have electric motors and the rest use diesel fuel as compared to over 95% electric connections for wells in SES1.

Table 9: Socio-Economic and Livelihood Characteristics

Indicators	Kinhola-Dawargaon	Kareli
Number of HH	475	91
Social groups (% to total HH)		
Scheduled Tribe	0.9	95.6
Scheduled caste	23	-
Other Backward Caste	30.1	4.4
Settled Nomadic tribes (VJNT/NT)	11.9	-
Upper caste	34.1	-
Land distribution (% land owned by HH)		
First quartile (Bottom 25% HH)	2.15	1.36
Second quartile (26-50% HH)	12.01	10.85
Third quartile (51-75% HH)	24.28	21.84
Fourth quartile (top 25 % HH)	61.3	65.95
Land holding categories (% to total farming HH)		
Large farmers	11.86	20
Medium	22.42	28
Small	39.69	28
Marginal	26.03	24
Primary occupation (% of HH)		
Farming	81.40	72.50
Agriculture labour	8	-
Non- agricultural labour	5.80	25.30
Service	2.20	1.20
Petty business	2.20	1.10
Livestock rearing	0.80	0.50
Education (% of population)		
Illiterate	4.60	4.40
Primary level	5.50	16.50
Secondary level	43.70	40.60
Higher secondary level	21.70	36.30
Professional and technical	6	1.20
Graduates and post graduates	18.60	1.20
Housing and sanitation		
Kutcha (% of HH)	11.5	92[20]
Pukka (% of HH)	88.5	8
Toilet facility (% of HH)	28	4
Household assets (number of units)		
Tractor	14	2
Car/Jeep/Mini Trucks etc.	10	0
Motorbike	179	16
Thresher	17	1
TV	212	22

Source: Study Census survey of HH

20 Houses do not have any uniform pattern in SES1 with either brick, cement or mud being used for walls and roofs constructed with concrete, asbestos or metal sheets. In SES2, there is clearly a pattern and uniformity in construction and similarity across all houses. The roofing tiles are made from local mud (locally baked) besides having clay and timber walls with clay and cow dung flooring. Here all materials for construction are mainly accessed locally and they classify them as semi-permanent structures where repairs are required once in 4-5 years.

different situations or characteristics are evident: SES2 consists of a community that is close-knit with strong horizontal communication within the community and across the tribe while having limited vertical communication with higher formal institutions/agencies and actors. In contrast, in SES1 communication spaces and channels are getting shrunk among the community while widening with the outside world. This also reflects on the availability of social capital and governance institutions. A right mix of formal and informal communication, social networks and governance arrangements are needed for managing resilience.

3.3 Socio-Ecological Interactions

The social sub-system intensely alters the watershed ecological sub-system for agriculture and livelihoods through changes brought in land use, aided to an extent, by the use of irrigation water. The most valued ecosystem service in one context is ground water and land productivity while, in the other it is a mix of surface and ground water, forest, land under agricultural and other uses. SES1 depends on extensive extraction of ground water. 82% of farming households have access to groundwater sources; there are 272 open wells and 16 bore-wells under private use in the watershed. 114 new wells have come up since the beginning of WSD, mostly under private ownership. Quite a few farmers who got a share in the family well as part of inheritance has also taken up individual wells. During the 70s there were around 10-15 wells and almost all of them had year-round water; the extraction was through traditional methods. With changes in cropping pattern, variations in climate affecting rain-fed farming and policies related to ground water development in these regions, the number of wells started increasing and now we see an unabated growth in the wells in most of the villages around. Studies show that watershed development is followed by an expansion in ground water extraction.

In both the SESs, there is considerable increase in ground water sources. The crucial difference among the two is while SES1 is intense in its ground water extraction and use, the other is very moderate and uses both surface water available in the stream and also ground water. The use is very sparse and crops are grown mainly on soil moisture with additional one or two waterings during Rabi. The land use is also being transformed; most of the common lands

Table 10: SES Typologies

SES	Socio-ecological stage[21]	Social sub-system	Socio-ecological system	Key characteristics of the system				Valued ecosystem services
				Diversity	Reserves	Modularity	Openness	
SES1(Kinhola Dawargaon)	Conservation stage (K)	Stratified caste based society (unequal ownership and access)	Highly managed agro ecological system	Very limited in agricultural, ecological and biodiversity components	Declining trend in both ecological and social reserves	Highly connected subsystems and components; trend showing shift and searching for alternatives/ autonomy (e.g., emphasis on education)	Highly open (impacts felt strongly if there are changes from above, like market or climatic fluctuations, etc.	Ground water
SES2 (Kareli)	Exploitation or growth phase (r)	Uniformity in social structure with a single *adivasi* community (unequal ownership and access)	Forest ecological system and moderately managed agro ecological system	Moderate to high level of diversity in managed ecology and also in biodiversity	Moderate to high reserves in both ecological and social reserves	Closely linked but loosely connected subsystems and components	Moderate openness; SES is relatively autonomous	Soil and water (ground and surface) Forest services

21 Ecological resilience suggests that systems move in an adaptive cycle from exploitation (r phase) to conservation (k phase) to release (Ω phase) and reorganizations (α phase). Connectedness across the system and potential are low in r phase and high in K phase (Holling and Gunderson 2002, Fridolin Brand 2005). However in highly managed SES there could be transformation not necessarily in the order.

in SES1 are encroached upon; agricultural land use is the only dominant system here while in SES2 we have a mix of various kinds of uses such as agricultural land, forest areas, grazing lands, groves and shrubs. More than 50% of the land comes under Common Property Land Resources (CPLR) here, as compared to less than 10% in SES1.

Such variations in water use and land use usher different trajectories of development, while at the same time, the social and cultural factors associated with the community determine the kind of approach towards land and water. Forest and trees are integral to the economic and cultural life in one (SES2), while for the other, these are not directly related to the economic or socio-cultural life. Almost all households in SES2 have part of their livelihood needs met from forest provisions. While land use and rights of use is a slow changing variable in resilience literature, it need not be so in certain conditions as we see here; the best example is the large level encroachment on community lands and converting them into other uses in both the SESs. Landuse under private holding changes fast. Land use diversity is getting reduced as more and more land is converted to agriculture, especially in SES1.

Section 4: Analysis of Resilience Traits: Magnitude and Distribution

Measuring resilience of an SES is not a conclusive exercise as it varies according to context, scale and values associated with what resilience is meant for the stakeholder. There are no conclusive set of indicators as mentioned before. What is considered resilient today may not be so in the coming years and accordingly the indicators may also change. In this section, we try to assess resilience characteristics using a set of proxy variables and attributes. The variables are arrived through an iterative process of theory and community consultation besides factoring indicators related to WSD objectives (ref. Fig. 2).

Resilience traits observed in all three sub-systems namely watershed ecology, forest and agricultural system and social and livelihood systems are analysed in detail. Thresholds, transformation and linkages of sub-systems and proxies are also analysed within relevant contexts. Resilience outcomes are looked into from the social and ecological points of view and also from the perspective of system interactions. Watershed development and other non- project factors such as policies, programmes, market, governance issues, system shocks work as drivers in facilitating changes and an attempt has been made to explain resilience outcomes in relation to these drivers. Besides analysing the transformational traits during the 'pre' and 'post' WSD phases, behaviours of the proxies during drought (for SES1 for the year 2012) of the SESs, a comparison with non-WSD villages (control villages) is also undertaken.While the focal system is the watershed/village unit, interactions below at farm and household level are also analysed in detail as that is the social unit that mainly interacts with the ecological unit.

4.1 Sub-system 1: The Watershed Ecology

4.1.1 Hydrology and Water Resources

Hydrology is the corner stone of watershed ecology and conventionally speaking, watershed development aims to manage watershed hydrology. However, most often, watershed development looks at water from the point of view of its availability rather than as part of a hydrological system linked across scales and uses. Drought affects the hydrological cycle immediately with reduction in the annual flow to the system. In a natural watershed system, some of the variables like the hydrological processes and aquifer characteristics are slow variables, which may be altered through technical interventions of watershed development. Some of these processes have long gestation times for such changes to occur such as improving the aquifer characteristics.

The subtractable nature of the resource (use by one person affecting the welfare or availability of the resource to another) makes management of water resources difficult (Kerr 2007); hence watershed development often aims to increase the magnitude and availability of the resource at the focal unit through various mechanical and vegetative interventions. The overall strategy is to reduce the runoff and convert moving water into a sedentary resource which helps in recharge and surface storage. Runoff reduction is expected to improve the availability of water at watershed focal system besides reducing soil movement, erosion and deposition. However, while this objective may ensure resilience at the focal system, it does not necessarily do so at scales above or below, namely, those who are in the downstream of the focal system. Studies show that reducing runoff at upstream levels coupled with increased extraction reduces water available for the downstream users. Local farming and other livelihood practices also determine how the resource is used and managed.[22] Given this peculiarity of the resource, it is important to see how watershed hydrology is influenced by WSD and how it contributes in enhancing the resilience of the SES.

22 The traditional 'Haveli System' of cultivation is very popular in Jabalpur District. Monsoon water is allowed to get collected in the fields and later the excess water is drained off and crops are raised from the residual moisture during the rabi season. This method is also found in the focal system (SES2).

Photograph 1: Well Water levels during the month of May 2015 in Kinhola-Dawargaon (SES1)

4.1.2 Geology and Ground water

The aquifer systems vary in both the locations and aquifer characteristics are not necessarily confined to the focal system. There could be a mismatch between the scale of surface hydrology, aquifer boundaries and the social scale. This could result in varying trends in availability and extraction of water within a micro watershed, as seen in this study. Where one is located in the watershed determines the chances of water availability. Proximity to the stream, the characteristics of the geology under one's land or the location in the catchment, for instance, influences this.

In SES1, the main source of water is shallow aquifers that show erratic variation in their ability to store and transmit water across small distance. This results in local variations in well water yields. Wells in such unconfined hard rock aquifers provide good yields depending on their location and material (fractured, weathered zone, hard rock etc.). Deep aquifers are also a potential zone and could be tapped through bore-wells, but it is very rare, as we see in our data. The main source of ground water is dug wells in the range of 40-70 feet depth.

The ground water potential and aquifer system is very complex in SES2 due to specific geo-hydrological formations. The focal area (SES2) is located in the soft rock aquifers mainly in the alluvium formation having both phreatic and confined conditions. Field investigation shows that most of the dug wells draw water from the seepage or subsurface flow as water is available a few feet from the ground level. The specific geological characteristic of SES1 would allow water to travel along the fractured rocks, while the alluvial and soft rock combination in SES2 is highly permeable, even though the degree to which ground water recharge potential exists varies. While water is

Photograph 2: Well Water levels during the month of May 2015 in Kareli (SES2)

available throughout the year in most of the wells in SES2, a large number of wells in SES1 are seasonal.

The reported average increase in groundwater levels across well owning households during a year of normal rainfall in SES1 is 5.78 feet while in SES2 it is 6.6 feet, as compared to the pre-WSD situation. While all the households from SES2 report increased recharge of wells, in SES1, 70% of well owners confirm increased recharge, 18.75% report no change and the rest of well owning farmers were not able to make a judgment. However, nobody reported drying up of wells in normal conditions even though three families reported their wells losing water due to new wells coming up in the nearby area in this focal system, while 20.83% report rejuvenation of completely dried up wells. On the other hand, it is important to note that SES1 which comprises two villages (Kinhola in the downstream and Davargaon in the upstream) shows some variation in perception between the villages. While 75% of farmers report improved recharge in the downstream village, only 47.5% report that in the upstream village. This shows the differential cost and benefits resulting from one's spatial location in a watershed. Resilience analysis of SESs also shows that resilience of one location could be subsidised by another location (Folke 2005). Since groundwater is a non-visible resource with unknown boundaries (from the community's point of view), its governance is a tricky issue, unlike more bounded and visible resources that the governance literature talks about. As such, we need to keep in mind that resilience at household level could be unevenly distributed as access to ground water is not equitable across various socio-economic categories.

4.1.3 Water Yield and Availability

In both the SESs, there is perceptible increase in the water yield and availability as reported by the community. While the increase in water availability is substantial at both the locations, there is also a concern raised by people about increased extraction in SES1 which lies in a drought- prone region. The watershed in this location also fared better during the drought of 2012 (SES2 did not face the shock) in comparison to the neighbouring villages. However, water for irrigation was limited to a very few wells while overall, the drinking water needs were met from wells within the village itself. In SES1, in normal years, only 12.17% felt a shortage for drinking and domestic water while 4.63% of

Photograph 3: Status of stored water in the local nullah during the month of May 2015 in Kinhola-Dawargaon (SES1)

Photograph 4: Status of stored water in the local nullah during the month of May 2015 in Kareli (SES2)

BOX 2: Change in water availability

While 87% respondents from SES1 and 98% from SES2 attribute the increase in water availability to watershed measures, those who report availability has reduced, attribute the cause to increased number of wells (7%) and excessive withdrawal (6%) in SES1.

farmers and 4.25% of livestock owners felt scarcity at some point of time for agriculture and livestock.

In SES2, only two families reported shortage of water as they are staying away from the village settlement and the drainage system. No shortage of water for agriculture is reported here. In fact, it is used sparingly and mainly during the rabi season. There is significant improvement in comparison to the scenario before the project in both the SESs: 26% and 20% had reported inadequacy in SES1 and SES2 respectively. In comparison to this, only 7.8% of the households reported inadequacy, for various uses throughout the year during drought in SES1, whereas in the neighbouring village (Dhabadi), 22% reported shortage throughout the drought year of 2012. While government tanker supply was regular for a year in this village, there was no tanker water supply in SES1. In Kinhola-Dawargaon, 87% of the people felt that water availability has increased overall; the corresponding figure for Kareli was 98%.

An analysis and comparison of the length of water availability (post-monsoons) in SES1 and the neighbouring control village in the pre and post WSD period (including the drought year) reveals the following situation:

Table 11: Water Availability in Wells/Bore wells of SES1 and the Neighbouring Village

Water Source	Wells			Borewell[23]	
Period	Present (2013-14)	Before (2002-03)	Drought (2012)	Present (2013-14)	Drought (2012)
Unit	Mean Months (Post Monsoon)				
Kinhola-Dawargaon (SES1)	7.2	4.9	4.9	2.7	0.2
Dabhadi (control)	4.6	2.9	1.2	0.0	0.0

Source: Detailed survey of sample households

23 There were no bore-wells in the project before the WSD intervention.

4.1.4 Change in Irrigation

Irrigation is a good indicator to understand the extent and change in water availability and extraction. Of the total cultivated area, 34% is rain-fed while 62% is seasonally irrigated and 3% is perennially irrigated in SES1; whereas, in SES2, it is 51%, 48.5% and 0.5% respectively in these seasons. The thrust of the cultivators in SES1 is to secure access to water, while the water dependence is relatively less in SES2. Mean irrigated land (in acres) owned by different farmer categories are as follows: in SES1 – large farmers (11.56 acres), medium (5.47 acres), small (3.55 acres) and marginal (1.56 acres) while in SES2 – large farmers (5.00 acres), medium (3.41 acres), small (2.75 acres) and marginal (1.30 acres).

Table 12: Change in Irrigated Area in SES1 and SES2

Change in irrigated area (area in acres)	Kharif		Rabi		Summer	
	Present	Before	Present	Before	Present	Before
SES1	1122.5	707.3	1065.87	507.8	60.9	6.1
SES2	4.6	-	180.2	95.2	1.7	0

Source: Study Census survey of Households

Rabi irrigation has almost doubled in both the SESs. Generally, kharif crops are rain-fed but for both cotton and maize, irrigation is provided as moisture stress is experienced and fertilizer application requires water. In comparison to this, SES2 mainly cultivates rice, Kodo and Kutki (both of which are minor millets) in kharif under rain-fed conditions only.

However, irrigation is unevenly distributed. Purely rain-fed farmers are higher in the small and marginal category (22.7% and 34.7% of farmers in these categories respectively) than among the large and medium (4.3% and 11.5%) in SES1. In terms of irrigated land holding (seasonal), the latter categories have a mean holding of 9.78 acres and 4.82 acres respectively. In comparison to this, the former two categories have only 3.9 acres and 1.23 acres respectively. Irrigation benefits often tend to tilt towards farmers who are located in areas in the valley portion and nearer to the drainage systems. Inequality arising out of location is often highlighted in watershed literature. In SES2 also, there are more households in pure rain-fed category among the marginal (44.4%) as compared to large farmers (20%). However, the small famers have increased their irrigation potential here after the intervention.

Water availability is the most significant attribute that ensures resilience for households in the face of drought. This was felt during the drought of 2012 in SES1 when people had to safeguard water for domestic and livestock needs. Most of the farmers reported water scarcity for agricultural needs during the drought. 88% farmers reported reduction in crop productivity, even though they felt that they were better positioned than their neighbouring villages. 73% of famers reported weather variations affecting their cropping pattern and cycle. During the drought of 2012, crop loss was reported in 39% of the cropped area under kharif in SES1 while, it was 53.5% in the neighbouring village (revenue data also support this). Famers could take a kharif crop but some of the crops like millet, maize and sorghum were used as fodder as there was no substantial grain formation and production of cotton was poor. In-depth interviews of sample households drawn from various categories of farmers showed that 56.76% of the area under kharif cultivation during drought had some applied water. Irrigation in kharif that year was very necessary to save crops as there was very little soil moisture due to deficient rain in the previous year of 2011. In comparison to this, the neighbouring village had only 27.3% of the area under irrigation during kharif.

However, the area under rabi crop has declined substantially during drought. Only 11.5% of the area was under crop mainly of sorghum which the farmers used as fodder to save their livestock. Overall, the area under fodder crops saw an increase in the drought period. Besides, a few farmers have saved 23 acres of horticulture crop (Sweet lime and Pomegranate), while some have lost the orchards. Rabi area in the neighbouring village also has declined substantially during drought. This brings us to the issue of water prioritization during stress. Those who have high value crops like orchards give priority for orchards, followed by fodder crops if they have high value livestock. However, most of them agreed that their first preference was for drinking, domestic and livestock needs, followed by food crops. Nevertheless, newly established orchards get priority as they involve high investment costs and if saved during the drought period even by purchasing water supplied by tankers, within three to four seasons of good harvests, they can break even.

In comparison to this, in a normal rainfall year (2013-14) we see substantial area under kharif irrigation- 86.4% of the area under cultivation had irrigation and most of the crops, other than pearl millet, had irrigation in SES1. Dhabadi, the neighbouring village, had 71% of kharif area under irrigation during the same year. This year, 88.63% of rabi area was irrigated as compared to 57.5% prior to the intervention in SES1. In Dhabadi the irrigated area in rabi is 75.38% of the rabi cropped area. This data shows the higher irrigation potential existing in SES1 as compared to the non-watershed neighbouring village of Dhabadi, despite it being in the lower part of the hydrological system and better favoured.

Kareli (SES2), as compared to SES1, has a non-intensive irrigation use pattern. Small area is under irrigation in Kharif (4.6 acres) and in summer (1.7 acres)[24]. This is irrespective of the fact that most of the wells and the drainage channels had water in the peak of summer when we conducted the field visit. Rabi irrigation, however, has almost doubled from 95 acres to 180 acres. From field observations, RS/GIS interpretation and agricultural production estimates, we could conclude that overall, it is a sparsely irrigated agricultural system.

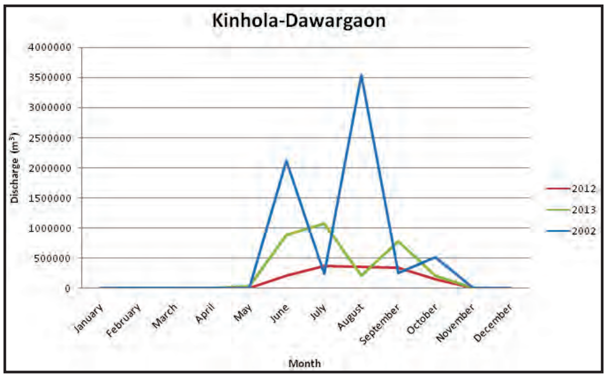
4.1.5 Runoff Analysis

Increased availability of water in the focal systems could be attributed to watershed development that aims to reduce the runoff velocity and improve the recharge. Various measures undertaken under watershed development have considerably reduced the runoff according to the community. 92.2% of the households report substantial reduction in runoff in SES1, while in SES2, 75% of the respondents says substantial reduction has occurred. Farmers' observations were based on the extent of rill and gully formations on the land and also the time

24 Interaction with the farming community on leaving the land fallow after winter crop, despite the availability of sufficient water for irrigation, they said the land is left for cattle grazing. This practice is a particular land use choice made by the community. Agriculture is viewed as a subsistence enterprise as compared to the other SES.

Table 13: Runoff Analysis Using SCS-CN Method (adapted for Indian conditions) in the SESs

	Annual runoff in m^3				
Year and Rainfall	**2002 (725 mm)**	**2011**	**2012 (337 mm)**	**2013 (674 mm)**	**% change in Runoff**
Kinhola- Davargaon (SES1)	4729826.3	–	1070702.2	2023888.9	57 (2002-2013)
Kareli (SES2)	2007695.6	1376765.7	–	–	31 (2002-2011)



Graph 2: Hydrograph of SES1

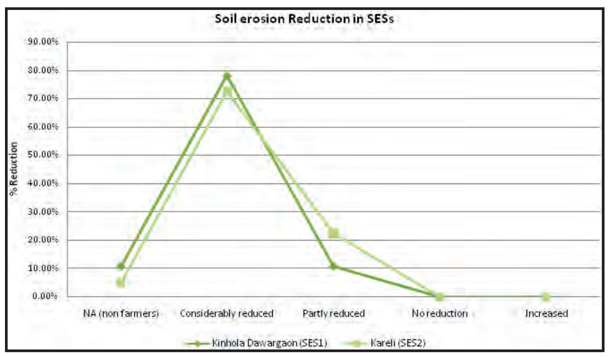
taken for terminal water harvesting structures to get water in comparison to the situation before watershed development[25]. Runoff, broadly speaking, is related to the rainfall, soils, land use and types of vegetation and changes in these variables would impact the runoff potential of a given hydrological landscape.

A runoff analysis was conducted based on hydrological boundaries of the project villages. The runoff was estimated using the SCS-CN method[26]. Since the watersheds were ungauged, this method is the most appropriate and gives reliable results. Using land use and land cover data generated through RS/GIS and factoring other influences/ drivers (such as watershed interventions, rainfall, etc.), the runoff was calculated for three temporal phases (2002, 2012 and 2013) in SES1 for two normal rainfall years (above 650 mm) and the drought of 2012 (337 mm) and for two phases in SES2 (2002 and 2011 with comparable rainfall of above 1100 mm). In SES2, we considered 2002 for the pre-intervention period and 2011 for the post-intervention period. Rainfall of 2011 is taken, as the gridded data for that period was available and not for the following years. Besides, actual daily rainfall data is not available in the public domain for SES2 location. For the site in Maharashtra (SES1) the actual daily rainfall for the area is available and factors used for the analysis.

4.1.6 Soil

Soils are another important component of watershed ecology. While soil types and properties change slowly, soil loss and organic contents are amenable and impacted by human interventions. Watershed development aims to reduce soil loss and improve the soil quality. Soil erosion reduction is reported by all farmers as the soil conservation work was fairly well spread.

Extensive bunding works helped in-situ conservation and improving soil moisture in both the SESs. However most of the farmers from SES1 (361 out of 388 farmers surveyed) report soil moisture loss and hardening of the surface during the droughts of 2011 and 2012. The system adopted for crop production and fertility management impacts this. Our study shows that the cultivation in SES1 is predominantly chemical (inorganic) fertilizer and pesticide driven as compared to SES2. There is indiscriminate use of fertilizers and pesticides in SES1. This not only impacts the soil but water resources also. The use of fertilizer is picking up in SES2 also. During the 2013-14



Graph 3: Soil Erosion in SESs as perceived by Farmers
Source: Detailed study of sample households

25 According to the community, the stream in SES2 has become perennial after the WSD intervention while stream flow is observed only for a month or two in the other.

26 The study used the following method adapted to Indian conditions: $Q= (p-0.1s)^2/p+0.9\ s$ for black soil AMC II and III; $Q=(p-0.3\ s)^2/p+0.7\ s$ for AMC I of Black Soil, and other Soils with AMC I, II and III. For details see Gupta P.K. *et al.* 2009, K. Subramanya, 2010, Vandersypen *et al.*, 1972, Ministry of Agriculture, GoI).

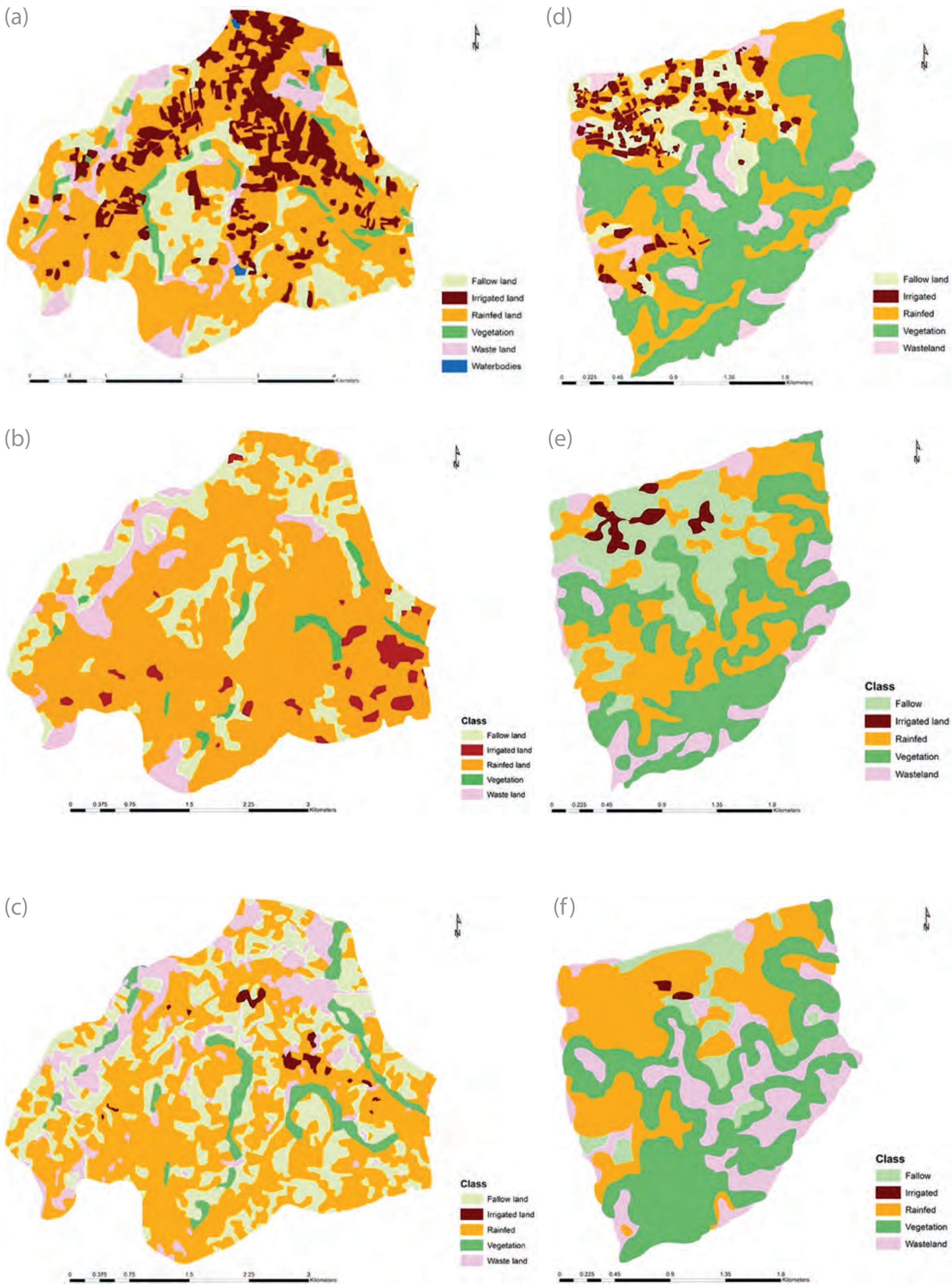


Fig. 3: (1) Land use at Kinhola-Dawargaon (SES-1) : (a) in the year 2013; (b) in the year 2012 and (c) in the year 2002; (2) Land use at Kareli micro-watershed (SES-2) : (d) in the year 2013; (e) in the year 2011 and (f) in the year 2002

farming cycle, 23 out of 37 famers in SES2 reported use of chemical fertilizers as compared to only one farmer before the project. However the quantity of application is very limited: 11 kg on an average per acre cultivated. In comparison to this, the average fertilizer application is 70 kg/acre in SES1.

Farm yard manure and biomass is still the main inputs in agriculture in SES2. Some farmers do not use either inorganic or organic fertilisers and cultivate using the nutrient deposits brought by rainwater. The use of farm yard manure and organic fertiliser is relatively very low in SES1. Only 54.5% farmers report use of farm yard manure, that also in alternative years. Earlier, there was a link between the type of crops grown and fodder availability which supported a livestock population providing various agricultural services. That chain has been broken over time and non-fodder crops like cotton have taken centre stage in this area. Increased use of pesticides and inorganic fertilizers changes the composition of the soil and also the water quality. Hence ecological resilience needs to be viewed within this context too. Watershed development could, if care is not taken (as is usually the case), impact the farming system in an unsustainable way, as we see from the emerging situation in SES1.

4.1.7 Land Use Transformations

The predominant land use as we have seen earlier is privately owned crop land in SES1, while it is an equal mix of both private cropland and common property resources consisting of trees, shrubs and grazing land in SES2. Here, we look into the changes the land has undergone specifically during the period of analysis and over the years.

Conversion of non-agricultural lands such as fallow, waste lands etc., to agriculture is conventionally considered as a positive development in watershed impact analysis. However, such a view needs critical assessment as diversity of land use is essential from a resilience point of view; more land under cultivation can reduce landuse diversity and sustainability (Joy and Paranjape, 2004). In SES1, the project completion report suggests conversion of 76 acres of private wasteland into cultivated land. Our discussion with villagers and also the household level data shows reduction of waste and permanent fallow lands as it is being converted for cropping.

Fig. 3 shows the changes in land use over the years in the two SESs respectively.

RS data shows that non-crop vegetation (say forest cover) is reduced in SES1 (-41.06%) while it has marginally increased (+9.21%) in SES2. As already mentioned, the latter has favourable common land resources in the form of forest and community land. While encroachment on public/commonlands is to a large extent underreported in SES1 (only 16 acres as per the survey), the extent of encroachment is 124.6 acres in SES2. During transect walks in SES1 we could observe large patches of land being converted, including houses being constructed in the previously demarcated common lands in the village map. In order to get a broader picture of encroachment, we analysed the time series data based on RS images and found that during the last 10 years, the area supposed to be under CPLR has reduced considerwably. Wastelands and land under sparse growth have reduced by 41.43% in SES1. While encroachment may be a strategy to expand agriculture, it is also seen as an economic activity as land prices are spiralling upwards in rural areas of Maharashtra. We tried to see whether it is the poor (landless) who encroached and our data shows that of the 12 households which reported encroachment, 11 belong to the landless while one is from the marginal farming households in SES1; in SES2 it is 10 households from the landless (of the total 42 households) reporting encroachment. Our interactions with various stakeholders in SES1 revealed that there are some landholders who have encroached on lands near to their farm but do not acknowledge it.

Land use and property regimes are considered as slow variables that can impact other land-related fast variables (RA, 2010). However, it could vary according to the context of interests. Access, use and ownership pattern could change during a short span of time due to political factors (as distribution of common lands in the State of Maharashtra) or through local events. As the ownership and property regime shifts, so do access and user rights on common property resources. In the case of SES1, the reduction in land under non-crop vegetation can be considered as diminishing ecosystem resilience (diversity in land use) on the

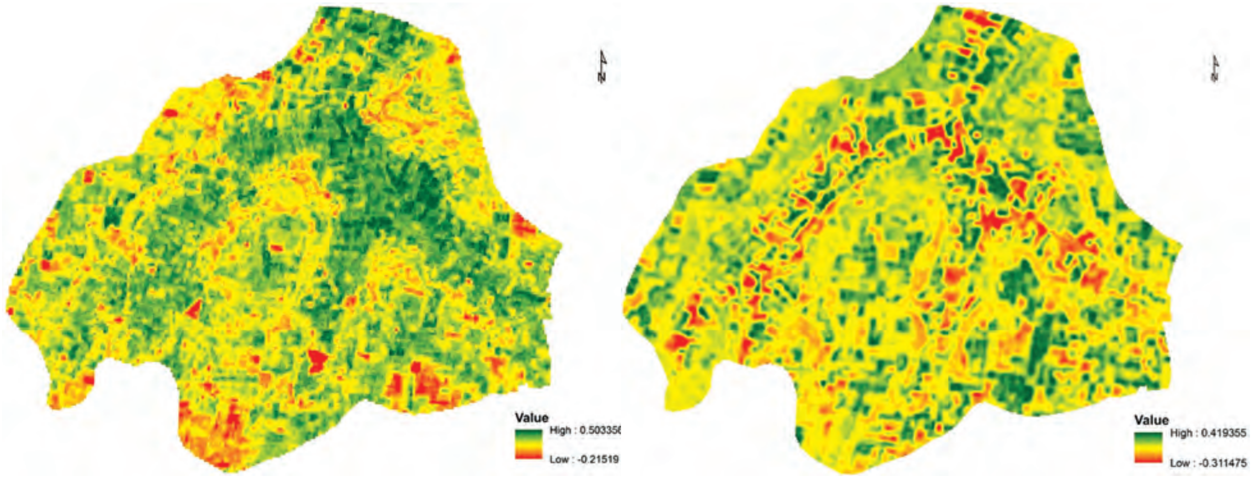


Fig. 4: NDVI of SES1 in year 2002 and 2013

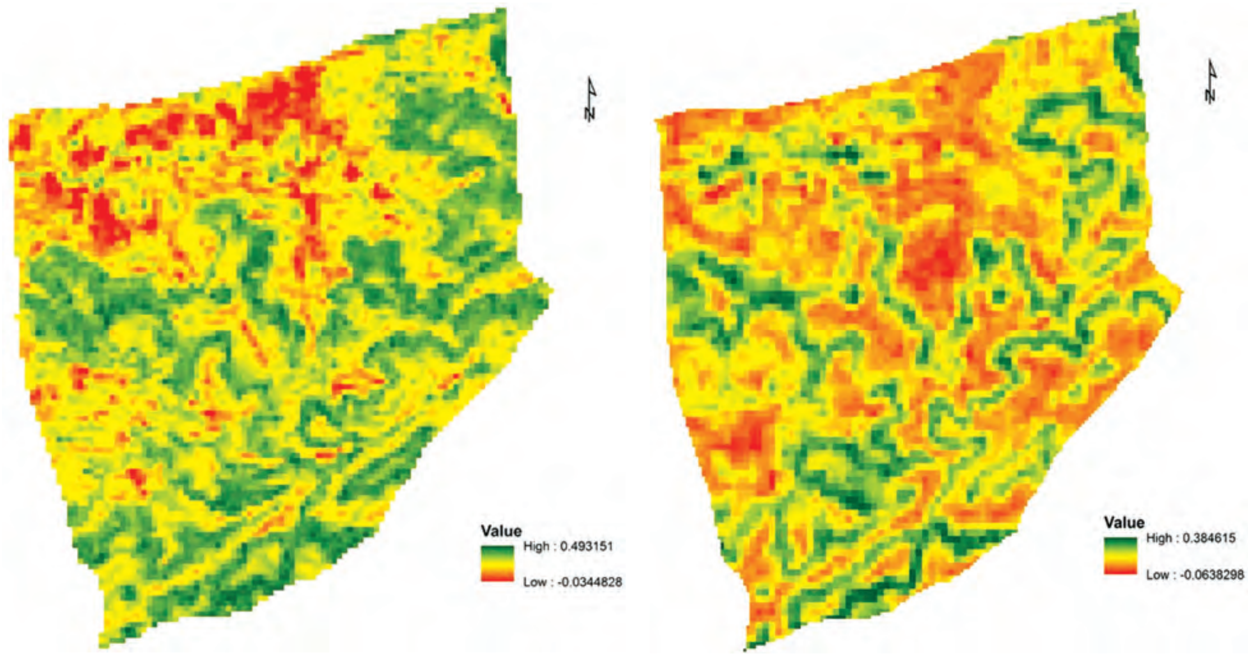


Fig. 5: NDVI of SES2 in year 2002 and 2013

one hand; on the other, it may be also contributing to increased resilience at the social and household level, at least for some households at a specific point or period in time.

4.2 Sub-system 2: Forest and Agro ecology

4.2.1 Forests

While forest growth is a slow changing variable, forest provisions especially grass, fuel, timber and other minor produce change fast. The growth and increase in canopy cover is not fast in the focal systems due to agro-climatic conditions. While inherited forest coverage in SES2 was comparatively good at the time of intervention it was mainly shrubs and grasses in case of SES1.[27]

27 The region (mainly Aurangabad and Jalna) has very poor vegetation cover. Describing the landscape where SES1 is located during the mid-half of the 19th century, the Gazetteer notes 'when the grass is burnt in the summer season, there is little verdure near to the villages and along some of the perennial streams. Everywhere else the black soil, the black rocks and the blackened tree stems present a remarkable picture of desolation. During the rainy season however, the country is covered with verdure, and in many parts it is very beautiful, the contrast afforded by the black rocks only serving to bring into relief the bright green tints of the foliage' (Ref. Imperial Gazetteer of Aurangabad 1870, p. 70)

Extensive plantation work was done in SES1 and social restrictions on tree cutting and free grazing were also established during the project implementation which resulted in forest growth and regeneration. However, the plantation is being lost to cutting and encroachment. For Kinhola-Dawargaon watershed, no difference has been observed in the vegetation cover based on NDVI as the maximum value is 0.5 in both years, Dec 2002 and December 2013. These values are generally the case for sparse shrub lands or grass lands. In 2012, the maximum value was 0.3 which shows vegetation cover had decreased during the drought year. If we observe and compare the time scale between December 2002 and Dec 2013, the spatial extent of exposed surface has been reduced over a period of time in SES2. In Kareli, NDVI values have increased over a time which indicates positive impact on vegetative pattern. As per the NDVI scale, barren/exposed patches of the watershed have been covered with vegetation. (Refer Fig. 4 and Fig. 5.)

4.2.2 Forest Provisions

Forest is not an economic resource in SES1 as compared to SES2: 84.78% of the households report income from small and minor forest produce. However we could see a reduction in the number of households reporting income from forest produce in SES2: 9 household do not access forest provisions now as they do not have sufficient members to go out and do the gathering. Since some farmers have extended their cultivation area, the availability of people to gather the produce has also reduced. People reported reduction in forest produce as a result of weather changes, mainly increase in temperature and heat. They reported less flowering in Mahua trees and early drying of Tendu leaves. They also report reduction in the duration of forest produce availability.

Interaction of the social system and ecological landscape for various services such as grazing and procuring fodder, accessing fuel wood, timber and so on is widely documented in the Indian context. This interaction is very limited in the case of SES1. This also reflects the lack of verdure and biomass availability in the focal system. Local observations show that most of the traditional grass varieties like Shaira (Chuneria), Jotishmadi, Punelia, Gundali, Trinpali,etc., have more or less become extinct. Kunda, Shama and Hariali often found in cultivated black soils are rarely found. The project spread grass seeds like stylohemata that are still

Photograph 5: NTFP collection in Kareli (SES2)

found on field bunds and mounds of CCTs and WATs. Only 9.38% of the households use common lands for grazing or accessing fodder while only 6.25% source fuel wood from there. The situation is not different in the neighbouring non-watershed village (Dhabadi) where hardly anybody gets either fodder or fuel from the commons.

In SES2, on the other hand, the intensity of the interaction is quite prominent. Almost the entire community depends on forests and to a large extent, on other non-forest common lands for both fodder and fuel wood. While 82.5% of the households reported accessing fodder from forest and other commons, the whole households in the village is dependent on the forests for fuel wood. Most of the fodder species still continue to grow here such as Phular, Ghosi, Bhains Khandi, Chirwa, Sheda, etc. More than 80% of their fuel needs are met from forests. However, the exploitation of timber from forests has reduced drastically as a result of Joint Forest Management. Earlier, almost everybody used to cut down some timber trees for own use and for sale; now only 25% of the households report taking timber, mainly for own use like house construction or repair. The reducing dependence of SES1 not only exposes the shrinking forest and common land services but also the changes in the life style patterns. In SES1, use of other energy sources such as LPG gas, electric and kerosene stoves, etc., have become very common. Fodder needs are met through crop residues, fodder cultivation and market purchases. This is an adaptation mechanism as well as reflects changing social and economic preferences. While there is a reduction in the green cover and vegetation, the community also felt that the drought has severely impacted the forest patches that were developed under the project.

4.2.3 Floral Diversity

Biodiversity signifies ecosystem resilience. The more diverse the SES in terms of flora and fauna, the betterisits resilience characteristics. Intensely managed socio-ecological systems based on efficiency and economics seldom value diverse ecological system. The social system invariably alters the biodiversity in managed ecosystems. Climate of the larger system, biota of the area, etc., influence the biodiversity as external drivers; but the local land use, agricultural and livelihood systems and social and cultural values impact it at the focal level. Even though we have not done an extensive biodiversity audit as part of data collection, the kind of qualitative information gathered and historical evidence suggest a dwindling biodiversity especially in SES1.

The Gazetteer of Aurangabad and Central Provinces gives a detailed description about the flora and fauna of both Jalna and Jabalpur Districts in which the two SESs are located. Mainly drawing from the botanist, biologist, or nithologist and other administrative catalogues one gets a beautiful and elaborate description of the natural and grown vegetation, crops, vertebrates, non-vertebrates, carnivores, birds, reptiles, domesticated animals, livestock and so on. While the location in and around SES1 is described as predominantly under agriculture with non-agriculture land being described as covered by long grass with a paucity of well grown trees, SES2 is characterized by agricultural land mixed with medium to large growing vegetation such as Mahua, Ber, Kachner, Teak, Sal, Saj, Haldu, Tendu, Bamboo, Char, Bhilma etc.

The main flora found in SES1 area is Neem, Babul, Khair, Umbar, wild Ber, Sitaphal and many varieties of thorny bushes. The gazetteer reports how cultivators have exploited most of the land and natural biomass has survived only in the stony and rocky areas around the villages, which is not land conducive for any vigorous growth of vegetation (Gazetteer, 1870 p 50). While almost all the species described here have survived over the years, their habitats and numbers have considerably shrunk.

4.2.4 Agricultural Sub-system

Agriculture is the backbone of the local economy in SES1, while forest resources also contribute along with agriculture, in SES2. Agriculture is rain dependent and any drastic changes in the rainfall pattern adversely affect the functioning the system. In this section, we analyse the agro-ecological system on some crucial variables such as agricultural diversity, crop choices and priorities, methods of cultivation and production which impacts as well as reflects the resilience of the system.

Social aspects of the system such as land holding pattern and agrarian relations change slowly, while other factors like input use and production see fluctuations. The social system in our case is characterized by small holder cultivators mainly using family labour. However, the crucial distinction between the two SESs is in the way the production system is being pursued. SES1 cultivates predominantly marketable crops using hybrid varieties of seeds and other external inputs while the other mainly produces consumable crops with local varieties of seeds and few external inputs. While SES1 is linked to a set of external actors and agencies such as private input providers, state marketing federations and companies, the former is relatively autonomous from these links. An 'open and highly connected' agricultural systemin SES1 would have different resilience traits as compared to a relatively autonomous system as in SES2.

4.2.4.1 Crops and Crop Shifts

SES1 shows shifts in the crops cultivated (dominant crops). Till the second half of the last century, crops included a large mix of cereals and cash crops like sugarcane mainly used for jaggary, cotton, various vegetables and varieties of chillies. In the later part of the last century, villagers cite predominance of sugarcane cultivation and small patches used for cereals, pulses and vegetables for household consumption. With water stress increasing, sugarcane cultivation ceased and now one cannot find even an acre of sugarcane in the village.

The 1980's saw the emergence of cotton and sweet lime and in the last two decades, the predominant crops are cotton and Makka (maize) with a few enterprising farmers having sweet lime orchards. Recently, sweet lime orchards are giving way to pomegranate which is a more hardy fruit crop. However, we should keep in mind that the changes were not always something that emerged from the community's initiative and adaption to water availability alone, but were also in response to the larger agricultural politics and policies of the region. Emergence of mono cropping of cotton in most of the area here should be seen in the light of the policies of monopoly cotton procurement started in 1971 by the Government under the Cooperative Cotton Growers' Federation. At present 86.5% of the area under Kharif is occupied by cotton (42%), Maize (29%) and Pearl Millet (15.5%) in SES1 even though there is a marginal decrease in the area under cotton cultivation (prior to the intervention cotton area occupied 46%). In contrast to this, the location in SES2 has seen continuity in the cropping system. It is, since centuries, a combination of minor millets (Kodo and Kutki), rice, pulses mainly tur (pigeon pea), chana (chick pea) and wheat. There are no ruptures or shifts and recently the watershed project has introduced improved cultivation practices through various demonstrations of crops and cropping patterns. As a result, vegetable cultivation has been started recently by 4-5 farmers. Even these, however, are small plots and used for local sale and home consumption. Even though the larger area in the District has various crops and crop shifts are evident from secondary data, the focal system remained more or less stagnant and stable in terms of type of crops cultivated. The State of Madhya Pradesh, as per available information, is one of the fastest agricultural growth States[28]; but looking at the mode of agriculture in the focal system one feels that it is as it has always been: continuity with little change.

While there are no significant changes in the number of crops cultivated since the watershed intervention, the area under various crops has seen changes in both the SESs. Prior to the project, there were 19 types of crops in SES1, which increased to 21 in the drought year and to 22 in 2013-14; in SES2, it has increased from 15 to 20 types of crops. However, area under various crops sees changes based on natural and external factors. For example, maize is becoming popular as a cash crop and families growing that have doubled during the period while the area has increased from 14% of the cropped area to 29%. This should be viewed in the light of problems being faced by the cotton cultivators and their adaptation strategy in the face of those vulnerabilities. Maize requires less water as compared to cotton or sweet lime. Other input cost like pesticides is also very less. Besides, it has a ready market for the poultry industry (located

28 After registering nearly 20 per cent growth during year 2011-12, Madhya Pradesh has once again claimed to have achieved a higher agriculture growth among all Indian States. Though the growth figures slipped from 18.91 per cent to 13.33 per cent, the total food grain production rose to 23.1 million metric tonne in 2012-13 against 20.3 million metric tonne in 2011-12 (Business Standard 23rd June 2013).

outside the State) and also in beer production, which has come up in the nearby industrial area. Farmers informed that traders from various part of the country come during the harvest season in the nearby market in Dhabadi. Similarly, the area under sunflower has almost disappeared owing to price fluctuations as a result of import liberalization. Better price and profitability, fewer requirements of labour, market availability and demand are found to be the reasons for shifts. In SES2 the area under Kodo and Kutki (minor millets) has come down and area under rice has gone up by 14.5%. However lack of market links and production mainly for consumption restricts crop shifts in SES2 unlike in SES1, as external links play a crucial role in such shifts.

4.2.4.2 Cropping Intensity

With increase in area under cultivation during various seasons, there is a substantial change in the cropping intensity (CI). In SES1, the CI has changed from 90.94 to 147 while the cropping intensity remained at 111 during the drought. In SES2, the CI has increased from 111.27 to 164.23. Cropping intensity in SES2 is comparatively better as it has a favourable rainfall. Cotton being a long duration crop stretching into the rabi period, most areas under cotton[29] cannot take up a second crop restricting the land use intensity. In case of the neighbouring village in SES1, the cropping intensity for 2013 was 141 while during the drought year it was 94. However, the cropping intensity in the neighbouring village of SES2 is almost the same as that of the focal system except, for the drought year when it reduced significantly.

Cropping intensity and area under cultivation in rain-fed conditions see year to year fluctuations influenced by the quantum, duration and timing of the rainfall, availability of ground water, soil type and quality, availability of residual moisture and so on. Recently, as the rainfall is shifting its onset (moving away from the month of June), the sowing gets delayed resulting in the second crop also being delayed or sown immediately after the harvesting of the first (kharif), as mentioned by farmers. The delay in the agricultural season is overall affecting the cropping seasons which in turn affects the production, cost of cultivation and so on. Extreme dependence on rainfall and ground water (and lack of diversity in water resources) is making agriculture quite vulnerable in SES1. However, drought has not drastically impacted agriculture here, at least during the kharif season, in comparison to the neighbouring village.

4.2.4.3 Crop Productivity

Productivity is an outcome of various factors, from the type of land to the kind of inputs, skill of the farmer and also choices made and values. We could observe a drastic difference in productivity in both the contexts. Just looking at two crops such as maize and wheat in both would illustrate the point (see tables 14 and 15 for difference in production of wheat and maize in both the SES). Productivity of all crops, except that of sorghum, has improved considerably in SES1, while the change is marginal for most of the crops in SES2. Rice and wheat, two principal crops show some improvement in this case. Better seeds, increased application of fertiliser, use of pesticides, availability of water and soil moisture (due to watershed work) and timely interventions are cited as reasons for improvements in production in SES1. Except for water, most of these inputs are not a significant input in the agricultural system of SES2.

Table 14: Productivity of Major Crops in SES1

Productivity of major crops in various seasons (quintal/acre) in SES1						
	Present		Before		Drought	
Crops	irrigated	non-irrigated	irrigated	non-irrigated	irrigated	non-irrigated
Pearl Millet	8.43	3.22	4.52	3.43	3.22	2.57
Cotton	8.37	6.35	4.44	3.52	4.80	3.38
Maize	18.88	12.85	11.56	10.07	14.14	8.98
Pigeon pea	4.85	1.88	3.73	1.72	3.025	1.174
Sorghum	3.09	2.83	3.68	3.02	Fodder only	2.20
Sweet lime	46.29		41.00		20 (pomegranate)	
Wheat	10.11	5.71	6.96	4.43	5.12	
Lucerne grass	200.00		100.00			
Chick Pea	2.97		2.02			
Turmeric	10.66					

Source: Detailed survey of Households

29 People also report shift in the cropping season resulting in cotton harvesting getting extended up to the months of February-March due to rainfall fluctuation and less rain in the month of June.

Table 15: Productivity of Major Crops in SES2

Production of major crops in various seasons (quintal/acre) in SES2				
Crops	Present		Before	
	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Rice	3.81		2.83	
Kodo	2.35		2.09	
kutki	1.49		1.67	
Maize	1.44		1.65	
wheat	2.32	3.15	2.31	2.07
chick pea	1.33	3.08	1.47	1.60
pigeon pea	2.08		1.80	
Black gram	1.53		1.53	
Masur	1.32		2.58	
Til (Sesame)	1.20		1.51	
green pea	1.35	1.33	1.76	
Vegetables		8		

Source: Detailed survey of Household

This could be explained by the cost of cultivation per acre reported by farmers in SES1. Before the watershed project, it was Rs. 6200/acre, excluding family labour, while it has almost doubled during the last one decade. The current cost per acre works out to be Rs. 12620. In comparison to this, the cost of cultivation in SES2 is only Rs. 903/acre at present.

4.2.4.4 Agricultural Income

Increase in income from agriculture is realised through higher investments in SES1 while the income or outputs have not substantially changed in SES2. The net income per acre in SES1 is around Rs. 12,000 while that of SES2 is Rs. 4,000[30]. Discussions with farmers in SES1 often gave the impression that agriculture is an activity they are involuntarily associated with due to the high cost of cultivation, poor returns and high risk involved in an unstable environment. However, the comparative increase of income from agriculture across land holding categories shows differences in the two SESs. In SES1, the income from agriculture has increased considerably among the big farmers, while in SES2 it is the small and marginal farmers who have improved their income. Increased area under rabi irrigation among the small and marginal famers could be a reason; concentration of household inputs like labour and manure also is cited as a reason, in comparison to large farmers who perforce have to spread their inputs[31] thinly. Thus, we need to acknowledge the fact that large holdings may not necessarily be profitable in all socio-ecological conditions.

Table 16: Gross Agricultural Income in SES 1 and 2

Gross Income from agriculture (per acre/per household)			
	Gross Agricultural income per acre of land		
SES	(present)	(before WSD)	(drought)
Kinhola-Dawargaon (SES1)	Rs. 23996	Rs. 9641	Rs. 13537
Kareli	Rs. 4924	Rs. 2086	-

Source: detailed household survey

Watershed development enhances resilience of an agricultural system even in drought years as mentioned by farmers in SES1 who have been experiencing two consecutive years of very poor rainfall. 59.4% of farmers report improvement in production in comparison to previous droughts. However, 88% of the famers felt that drought has resulted in decline of crop production and 37% reported crop losses, even though a majority of farmers (78.3%) felt that watershed development helped in coping better than would have been otherwise.

Detailed interviews at household level show production losses in the range of 35-40% for SES1 during drought, while the same is around 65-70% in the neighbouring village. According to the famers, the resilience of crop production has also increased considerably: for normal years only 4.5% of the farmers report 'no change', while rest of the farmers either report considerable improvement or

30 The income from agriculture is influenced by various factors: factors of production such as land, labour, water and other inputs, besides the agro-climatic context and cultural issues. Given this, the income would vary across regions and households. The growth in agricultural income as a result of watershed development could at some time increase inequality. In order to understand this, we analysed the Gini-coefficient of agricultural income. In SES1 there is not much change (0.55 earlier and 0.54 now,) while in SES2 it has reduced (0.51 earlier and 0.44 now). This is a result of more marginal and small farmers realising increased productivity as a result of moderate increase in area under cultivation and production after the WSD intervention. We have also seen that the gross cultivated area and access to irrigation has increased amongst this section in SES2 as compared to SES1.

31 Such as home labour and manure which is in about the same quantity available to small farmers but which has to be deployed over a larger area.

partial improvement in productivity.However we need to factor that productivity increase is a result of many other factors also, as seen earlier.

4.3 Sub-System 3: Social and Livelihood Sub-system

In a coupled and highly managed SES such as watershed landscapes, the social sub-system influences the ecosystem while simultaneously being dependent upon it for various services. In the socio-ecological rural landscapes, livelihoods are closely linked to the ecosystem resources which make the interactions between these two systems dialectical and reciprocal. The social system is also the key driver or agency in adaptation. Human beings, through various institutions, governance strategies, technologies etc., mediate these interactions with the objective of creating conditions that make for a 'better' life.

4.3.1 Watershed Development and Adaptive Governance

Watershed development – the main 'driver' that distinguishes our SES from other similar kinds of rural socio-ecological productive landscapes – introduces several institutional and governance mechanisms in the form of social capital and regulatory strategies for resource management. At the same time, resource management is also influenced by non-project and non-focal factors at various scales – broadly, the State and State institutions, the family and social groups or social networks. Resilience literature talks about adaptive governance or adaptive co-management of SESs which can foster resilience. Such a system of management is based on institutional and governance mechanisms and collective actions based on social networks, trust and appropriate leadership. The response to changes would be addressed by overlapping institutions and governance mechanisms. The principles of such a governance system would be based on diversity, inclusiveness and flexibility. The sharing of management power and responsibility may involve multiple and often polycentric institutional and organizational linkages among user groups or communities, government agencies, and non-governmental organizations, which neither centralize nor decentralize, but facilitate cross-level, interactions (Pisano 2012).

4.3.2 Community-based Institutions

Participatory watershed development ensures the formation of rules and institutions during project implementation. Studies show that they do not sustain and governance of common resources takes a back seat. The institutional arrangements under the intervention are project-driven and can have serious limitations in ensuring participative governance. Property rights and legal regimes around resources such as ground (and surface) water or forest biomass also impact the resource governance. The data from the field suggests that the community initiative for governance of common resources is not functioning as it should have been, especially in SES1; institutions created as part of the projects like SHGs, VWC, FPC etc., have largely become dysfunctional or dormant.

Various indicators on participation (participation in planning, implementation, voluntary contribution, monitoring, etc.) of the community show significant difference among the two SESs during project implementation. In SES1, the participation is moderate to low at household-level while, SES2 has a high participation level. More than 80% of the households show active participation in planning, implementation, voluntary labour, education and exposure and so on. While SES1 is a stratified social landscape as compared to SES2, the complexities involved in collective action are very different. There are many existing inequalities based on caste, livelihoods and culture in a caste-based society such as SES1. The reasons cited for non-participation were personal (busy with personal work), not being aware of the project or internal conflict and exclusion. The dalits and the landless felt they were excluded from many of the project decisions. In comparison to this, one could see a sense of unity in SES2. The leadership is also accepted and respected by fellow villagers.

Resilience literature cites that building knowledge and understanding of resources and ecosystem dynamics is an important component of adaptive co-management/governance and suggests that attempts should be made to mobilize all knowledge related to the ecology, its processes and interactions within the social subsystem. Development projects, to varying degrees, aim to achieve this through various capacity building initiatives and in this regardthe watershed development work in both the SESs was no exception (see Table 6). However, there is no continuity of the process. Acquiring knowledge and learning are not limited to resource conservation alone in an adaptive co-management system, but is an ongoing iterative process that helps in adapting to new challenges or converting disturbances into opportunities. This is very important in the face of climate variations and when evolving effective strategies for adaptation. Strong feedback loops are an essential component of a resilient social eco-system. In the post- project period, there is no continuity and facilitation to address emerging needs. A short-term project-based approach has serious limitations in this regard.

4.3.3 Resource Management

Maintenance and management of assets created as part of the intervention by the community and local institutions is a proxy to understand the continuity of created institutional arrangements. The Watershed Committee (WC) is expected to maintain and manage the resources created as part of the intervention. We did an audit of 21 water harvesting structures (19 cement and 2 earthen structures) in SES1 besides various land works. Most of the water harvesting structures are silted (11) or partially damaged (10). Conservation measures on private lands are partially maintained by farmers but plantations on common lands are more or less lost. All households report that the measures on common property resources have been lost naturally due to drought as well as through human interventions such as encroachments. The status in SES2 is also not very different. Three out of 6 water harvesting structures created as part of the interventions are silted and partially damaged. Maintenance of created structures and physical assets are important to ensure continued resilience and responsive, adaptive capacities to extreme climate events.

Sustainability of resources becomes crucial if impacts are to be sustained. We have seen that watershed development is followed by considerable acceleration in ground water extraction and use. In locations where agriculture is market-driven and the resource base is precarious, in all probability, there could be undesirable outcomes and 'regime shifts' in the long run if resources are not managed properly. Ground water has become one such "hot" issue. Because of the nature of access rights linked to individual landowners, it has become a 'non governable common'[32]. In response to the question of mechanisms in place for judicious use of water, the responses of the villagers are as in Table 17.

The "yes" response in normal years refers to use of technical options like sprinkler and drip irrigation rather than community governance and regulations mechanisms. During drought, the 'yes' means water sources are reserved for drinking water purpose. In terms of ensuring user rights, there is no preferential treatment for the resource poor; everybody has equal access to resources, according to the community.

In both the SESs, the traditional leadership and networks were incorporated into the management of the watershed project. The outcomes are different. While the one located in a highly stratified and

Table 17: Institutional arrangements for judicious use of water

		is there a mechanism for judicious use of water?		is there a mechanism worked out specifically during drought/shocks?	
		Yes	No	Yes	No
SES1	Count	1	63	7	57
	%	1.6%	98.4%	10.9%	89.1%
SES2	Count	5	35	5	35
	%	12.5%	87.5%	12.5%	87.5%

Source: Detailed survey of households

32 There are attempts to regulate the use and extraction of ground water through State Policies and Acts. The Maharashtra Groundwater (Development and Management) Act, 2009, which got the President nod recently (2013) with the stated objective 'to facilitate and ensure sustainable and adequate supply of groundwater of prescribed quality for various categories of users', is a step in this direction. Under the law, wells and bore-wells will have to be registered, and in areas notified as critical in terms of groundwater extraction, well-digging will be restricted. Depth of wells and bore-wells will be monitored and digging beyond permitted levels will not be allowed. Use of water from existing deep bore-wells and wells will be taxed. The law also provides for restrictions on excessive use of fertilizers and pesticides to prevent ground-water contamination. However, with large numbers of users (like 380 users in a 1500 ha watershed like SES1) no regulation can result in anything tangible if it is not community-driven and tailored to the local dynamics. However, community initiatives in successfully managing ground water resources are very few and far between.

hierarchical social space was not able to generate an inclusive process, the other was successful because of the specific social and cultural context. The project interventions in SES2 were also biased in favour of the marginal and small farmers to which there was no resistance from the others.

4.3.4 Formal Institutions

The State agencies are integral to the developmental processes and arrangements are designed to achieve fixed targets rather than evolve strategies that ensure adaptation in the face of climate-induced shocks. While in normal times the community is linked for various services and provisions, during shocks the Government agencies and political establishment become the most sought after agency for public works that ensures wage employment, cattle camps, tanker drinking water service and so on. Persistent drought and continuous drought relief is a regular feature that has created many systems of patronage in SES1. We tried to understand this in our field work. There was no tanker supply here, but the Collector has notified private wells for public drinking water and domestic purposes. The cattle camps have become popular as around 30 farmers have kept their cattle in those camps and many others got fodder (mainly sugar cane) from government-run depots.

Compensation for crop loss under drought relief is where most of the farmers have to deal with government agencies in SES1. This involves a series of patronage and networks linking the farmer, the local official land recorder (a revenue officer called a "talati"), the sarpanch, and the revenue, agriculture and relief and rehabilitation departments and so on. Estimating the extent of loss and valuing the same is also a process immersed in power and patronage. Crop survey was done after September 15th in (2011 and 2012), followed by another survey by the end of the kharif period and the beginning of winter rabi. Data is accumulated at tahsil level and compensations fixed based on decisions taken at the state-level for various types of crops. The compensation money disbursal takes its own time and famers receive the money only after a few months and sometimes, not at all. Everything, according to them, depends on your links and relationships with the officials and political networks. Our data shows that 80% of the farmers in SES1 got compensation while in the neighbouring village only 68.8% received it. Compensations were given to 57% of respondents in SES2 who lost some crops destroyed by heavy rain.

Assessments show that the investments in drought relief during 2012 in the region were more than the entire planned development investment for the region for the same year. The drought in the region is a result of the lack of good water governance mechanisms whether it is for ground water or surface water of the irrigation systems and various other reservoirs (Purandare, 2013). The role of the State in facilitating governance and also ensuring regulatory structures is crucial for resource governance at local and other scales. But most often, it just attempts to address the supply side immediate constraints and does not adopt an integrated approach to tackle the emerging crisis by taking into confidence the stakeholders and handing over the responsibilities to them. Attempt is to 'absorb shocks' rather than facilitating adaptation through inclusive and flexible governance strategies.

4.3.5 Livelihoods

The interaction of the social and ecological system is premised on ensuring livelihoods and socio-economic progress for the watershed dwellers. A major objective of watershed development is to ensure livelihood resilience through building resilience of the ecosystem services mediated through social and institutional mechanisms and other innovations. This does not mean that there is always a positive resilience relationship between ecosystem services and livelihoods. Livelihoods could be enhanced at the cost of degradation of resilience of the ecosystem services and vice versa. Thus the importance of developing sustainable livelihoods through sustainable management of natural resources becomes important in resilience building.

In a traditional agrarian economy, livelihood sectors are mainly a slow variable as the occupational profile is socially and culturally determined. Continuous vulnerability forces people to adopt some mechanisms such as migration which is not only an economic and livelihood adaptation, but also a social adaptation which helps in finding a way out of traditional social exclusions. The occupational diversity of the households is very limited in both the SESs. Agriculture is the primary occupation and contributes almost over 80% of the food and financial requirements in SES1 and, to a lesser extent, in SES2. Demand for unskilled and semi-skilled work is increasing in the nearby towns and cities which are slowly emerging as an adaptation mechanism as the returns in terms of wages are better. Forest provisions contribute significantly to cash and other livelihood requirement in SES2 [ref. Section on Forests (4.2.1) and Forest Provisions (4.2.2)].

4.3.5.1 Agricultural Livelihoods

Table 18 shows that agricultural income has played a growing role in HH income and could well reflect the productivity gains realised due to WSD, as seen in the last section. However, it also underscores increased vulnerability as dependence has grown on a nature-dependent source of livelihood.. Income increase is unevenly distributed. The mean income from the same for the large farmers in SES1 was Rs. 488,340[33]. In comparison to that, the mean incomes of other farmer categories in SES1 are: medium (Rs. 168,314), small (Rs. 125,408) and marginal (Rs. 79,812). The landless category also earns some agricultural income (Rs. 34,700) through lease in and encroachment of common lands. The income in SES2 is not as skewed as in the former and inequality has reduced. The average income among large farming households is Rs. 78,898 while that of small and marginal farmers is Rs. 33,950 and Rs. 26,685 respectively. Agricultural income of marginal farmers in a normal rainfall year is higher in SES1 than that of the large farmers in SES2!

BOX 3:

Gini coefficient for agricultural income shows that income inequality has reduced in SES2 (0.51 to 0.44) and remained more or less the same in SES1 (0.55 to 0.54) as compared to pre-project situation. Income inequality in the drought year rose to 0.61.

4.3.5.2 Non-agricultural Livelihoods

As cited earlier, farm and non-farm labour including migration, livestock and forest mainly contribute as other livelihood sources. The share of agriculture labour is not very significant in both the SESs.

There is an improvement in most of the income sources as well as in overall income except from livestock component. It is a resource that fluctuates regularly, depending on factors based on the household economy, human resources, other input factors such as fodder and water availability and also external drivers like climate, market, institutional set up, culture of the community, etc.

Improved income has also resulted in increased savings. In SES1, 56.25% of the households report different types of savings or investments in productive or speculative assets during the last three years; while in SES2 41.5% report the same. The mean savings across all categories of families reporting savings/investments during last three years (two droughts and a normal year) is Rs. 347,869 in SES1 while it is only Rs. 25,796 in

Table18: Share of Agricultural Income in the Total Income in the Households

Percentage of income from agriculture in total income among farming households								
	SES	Time frame	up to 40%	41-60%	61- 80%	81- 90%	91-100%	Total cultivators
Number of Households	SES1	Present	91	97	116	33	69	406
		Before	128	93	91	33	49	394
	SES2	Present	21	18	28	7	5	79
		Before	28	24	21	2	3	78

Source: Census survey of Households

33 This is after excluding a big farmer who owns 90 acres of land having an overall agricultural income of Rs. 33,12,600 per annum; if we factor in this case, the mean income goes above Rs. 7 lakhs/large farmer.

Table 19: Non-farming Livelihoods

Indicators (values for 2013-14)	SES1	SES2
Migration based livelihoods		
Households migrating (%)	16.8	76.9
% to total population	6	23.5
Change in migration	Marginal increase	No change
Average annual income of migrating Households (Rs)	Rs. 13000	Rs. 15500
Agricultural labour livelihood		
% HH (as primary and secondary)	28	1
% change in HH engaged	Reduced by 3%	No change
Average annual income per HH (Rs)	6300	2000
Livestock based livelihoods		
% of HH reporting as a main occupation	3.3	1
% HH owning Livestock	78	89
% Change in HH owning livestock	+6	-4.5
% HH reporting income from livestock	26	7.5
Average annual income from livestock (Rs)	6482	1500
Service/Business etc		
% HH engaged	11.28	7.70
% change in HH engaged	+9.25	+5
Average annual income among HH engaged in the same (Rs)	129712	32425

Source: Study census survey of HH

SES2. Savings/investments are in land, buying a house in cities (SES1), jewellery, livestock, business investments etc. In SES1, 76.6% report de-saving, while 37.9% report borrowing money during the period. In SES2, the de-saving households are only 27.5% while those who borrowed during the last year (2012) were 30.2%.

4.3.5.3 Other Socio-Economic Indicators

Availability of Drinking Water

Availability of water for drinking, domestic use, livestock and food security are other key variables to understand livelihood resilience. In a drought-prone region, drinking water availability throughout the year is one of the main concerns. In the Jalna district, this is found to be a severe problem. During the drought of 2012, 483 water tankers were providing drinking water to 376 villages and 104 hamlets in the district (Purandare 2013). This is besides what farmers on their own procure and what NGOs and political organizations provide. Even in normal times, many of the villages have difficulty in getting drinking water during the summer months. Resolving this is one of the main objectives of the State and other agencies. In both the SESs, people depend on multiple sources such as piped supply, wells and bore-wells of both common and private ownership, the local stream and so on. In normal years, nobody generally felt that they have difficulty for water for drinking and for other domestic uses.

Table 20: Households facing water scarcity during drought periods

	Water scarcity is faced for:		
	Drinking water	Domestic use	Livestock
SES1 (during drought)	55 (12.11%)	26 (5.73)	15 (3.30)
SES2 (normal year)	2 (2%)	2 (2%)	1 (1%)

Source: Census survey of households

In SES1, during normal rainfall like last year (2013-2014), there is no water scarcity for drinking and domestic use. In case of the other SES it is very insignificant. Some of the households in SES1 reporting scarcity stay on their farm and indicated that water in the well dries up during the summer months. However, they also mentioned that they can access drinking water from other's wells or come to the main settlement and carry water which is available there in public hand pumps or wells. To a large extent, even after two years of drought, the community had a sufficient resilience with regard to drinking water. While only 7.8% of the households reported scarcity throughout the drought of 2012 in SES1, 22.5% of households in the neighbouring control village reported water scarcity and 40% households reported that they were exclusively dependent on water tankers. There was no tanker in SES1.

Food Security and availability

Incremental production should result in food security at household level. There are interesting changes happening in the villages especially those in the region where SES1 is located. There is a shift in cropping pattern as we observed and more and more farmers are growing cash crops, mainly cotton and maize. For example, 15.56% of farmers in SES1 do not cultivate any cereals consumed

Table 21: Households cereals availability (produced at own farm)

SES		Surplus	Sufficient for the year	For 8 months	For 4-8 months	Less than 4 months	Not produced at all on own farm
SES1	Present	32.80%	35.90%	10.90%	4.70%	0.00%	15.60%
	Before	6.30%	35.90%	21.90%	15.60%	1.60%	18.80%
	Drought	3.10%	35.90%	17.20%	15.60%	7.80%	20.30%
SES2	Present	15.00%	47.50%	27.50%	5.00%	0.00%	5.00%
	Before	2.50%	20.00%	45.00%	15.00%	10.00%	7.50%

Source: Detailed survey of Household

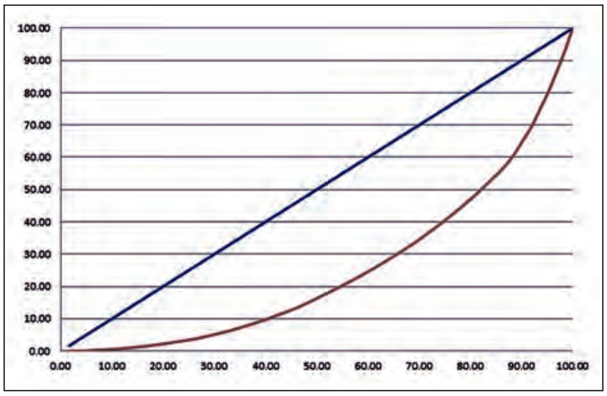
locally like millets and wheat. In SES1 there are very few farming households that experience food shortage even though they are growing mainly cash crops as they meet their requirements from the market; even during drought there was no food deficiency, according to people. Among the landless also, food shortage is not found to be an issue, of late. They also report that the situation has considerably improved over the years. However, we are not referring to nutritional security as it would require a different assessment.

Other food items like pulses and vegetables show an increasing dependence on the market in SES1 as compared to the other SES. In SES1, 58.5% HHs have sufficiency in pulses while 28% depend fully on the market for the same; in SES2, only 10% buy this from the market or neighbours. Vegetables are mainly bought from markets (81% in SES1 and 20% in SES2). For milk and other milk products, 51% of the households in SES1 and 67.5% of the households in SES2 depend on the outside. The overall picture that emerges is that while there is self-sufficiency for food items at the farm level or from neighbours in SES2, the other is more a market dependent food system as their needs and wants are also different.

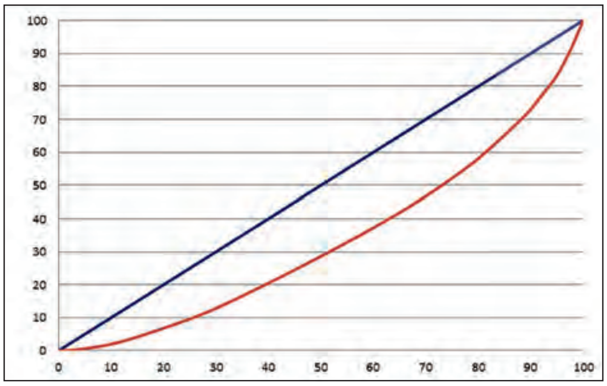
4.3.6 Income Inequality

Using income from all sources, the Gini coefficient for income of 2013-14 (present income) was assessed and the result shows a far more equitable situation in SES2 than in SES1. The values for SES 2 are 0.350 while that of SES1 is 0.501. We have plotted the Lorenz curve[34] (refer Graphs 4 and 5) and it reflects that the inequality in SES1 is more pronounced than in the other SES.

As per the Lorenz curve, the bottom 25% of the population has only 3.11% of the income in SES1 while in case of SES2 it is 9.60%. The top 25% of the population has 60.02% income in SES1 and 47.73% in case of SES2. This shows fairly different



Graph 4: Lorenz Curve of income inequality in SES1[35]



Graph 5: Lorenz Curve of income inequality in SES2

34 Lorenz curve or the Concentration curve depicts the cumulative distribution of the income across different quartiles of the population; the 450 line depicts the perfect equal distribution (e.g. 10% population having 10% of the cumulative income) while the curve represents the actual values. The Deviations of the actual cumulative distribution – the so-called "Lorenz or Concentration curve" – from the 450 line then denotes the degree of inequality of the income earned. The more bent the line of the Lorenz concentration curve is, the more unequal is income distribution across the population.

35 The x axis represents percentile cumulative HHs and the y-axis represents percentile cumulative income.

Table 22: Community Rating on Benefits from Watershed (% of Households in SES 1 and 2)

Village Name		Benefits got from watershed development				
		Highly benefited	Moderately benefited	Somewhat benefited	No benefits	Total
Kinhola-Dawargaon	Count	87	205	115	44	451
	%	19.3%	45.5%	25.5%	9.8%	100.0%
Kareli	Count	28	49	14	0	91
	%	30.8%	53.8%	15.4%	0	100.0%

Source: Census survey of Households

patterns of income distribution across the two SESs. While one is more subsistence oriented, 'low growth' and equitable, the other is fairly high productive, commercial and inequitable.

Overall, we observe considerable improvements in the resource base, production system especially agriculture, income, assets and also livelihoods. This would also mean a better resilience at the household levels even though the benefits are not always fairly distributed and are impacted by land holding, access to water, the location of one's land and other social aspects. While in SES1, the social subsystem built this resilience over the years through substantive alterations to the ecosystem, this is not the case in SES2. Socio-cultural factors and values also impact the way resilience strategies are adopted and livelihoods and incomes are realised.

The perception of the community also shows that WSD has brought changes in the overall natural resource base and in livelihoods. All 64 sample households interviewed in SES1 felt that WSD helped in better drought proofing and the majority felt that they had benefitted from the intervention, as indicated in the Table 22.

While the response of members of the community would largely be based on their income and livelihood returns, they may not be taking into consideration the type of interactions and the possible thresholds, the natural resources such as water, land and biomass they could reach. However, from a conventional impact point of view, the WSD intervention did generate greater production and incomes from agriculture resulting in better coping up ability during the drought. Nevertheless, how far watershed development alone has contributed to this remains an issue of attribution. SES1 which shows considerable increase in production also shows substantial increase in inputs, while SES2 shows marginal increase with marginal inputs. In the coming section we analyse these changes using the 'socio-ecological resilience' schema of characteristics as elaborated in Section 1.3.

Section 5: Resilience Characteristics of the Watershed Socio Ecological Systems

In the previous sections, an attempt has been made to explore the transformational traits in the two SESs.These two SESs represent the rural landscape in the dry land regions of India. While SES1 is a fairly developed and highly influenced agro-ecological system, the other (SES2) is subsistence-based in the early stages of growth and has a moderately managed forest agro-ecological system. While the interaction of the social and ecological systems is highly anthropocentric in SES1, the situation in the other is less so. Given these two different topographies, we can expect two different pathways of transformations and resilience characteristics, system linkages and threshold levels. In this section, we will attempt to analyse these out based on the conceptual framework and resilience properties elaborated earlier.

5.1 Links and Outcomes

An SES is linked across sub-systems, their components and variables in various spatial and temporal scales. We have focused mainly on the micro watershed as a focal system and its extensive links to the lower scale of farm and households, and to some extent, the larger scale above. The information available regarding the temporal scale is limited in range in some components given the problems of data and information availability. While the literature on resilience highlights the non-linearity of linkages and relations between a sub-system and its components, it is important to acknowledge that the links and relations are often dialectical in coupled production landscapes.

We have two different topologies; hence, different socio-ecological and livelihood subsets having different components and linkages resulting in different interactions and outcomes, as we have seen.

In SES1, the links are asymmetrical and dialectically reinforcing the behaviour of the variables. Hydrology and ground water, the crucial ecosystem service at the focal level are linked to external drivers such as weather variations and impacted by the behaviour and choices at farm and household level. The production system is highly linked to ground water; but its natural shortage (as the focal areais in a drought-prone and low rainfall region) creates competitive extraction which is resulting in depletion in the ground water stock. Intensive extraction at household level reduces the availability in the larger system and also for other households due to the subtractive nature of the resource. Establishing these links and anticipating the outcomes is very crucial from an adaptive management perspective.

While water resources and other ecological services are closely linked to the agro-ecological and production system, the nature of production system pursued, in turn, is influencing and impacting the ecosystem and its services. The resilience strategies at household level determine the ecological limits for growth and development; the kinds of choices are linked to the external larger systems like markets, service providers, companies, etc., for various inputs. The production system followed is linked to reducing diversity of both crops and other biota while ensuring short term profits and reserves for periods of stress, such as bad weather, drought, and adverse market conditions. Maximization of agricultural land use is linked to shrinking land use diversity and provisions for fuel, fodder and other ecological services like controlling erosion, pest control and pollinations functions. The people acknowledge the relationship between the slow variables and their link to fast variables but nevertheless ignore these in the desire to realise impacts that are swift and visible. The social system is closely linked to the ecological system, as it should be in any SES, but the feedback and response loops are weak resulting in poor management of the resources.

In SES2, the links of the three sub-systems and its components are strong and mutually reinforcing, as in case of the former. However, there is qualitative difference in the links due to external drivers like climatic factors, agro-climatic contexts, the choices, the social systems pursued and the resultant agro-ecological and livelihood systems. The production system here is linked to hydrology and water resources to some extent, but is relatively autonomous as compared to SES1 – better soil moisture regime due to favourable rain and agro-climatic conditions allow production which is not highly dependent on applied water. The production system is largely autonomous of market and input links. The subsistence production choice allows such a lack of links even though it comes at the cost of low productivity. Low productivity is a result of low inputs. This may be the result of low levels of resources for obtaining inputs or inherent in the community's value system which does not lay stress on high energy input production.

There is a close link of the production system to the local ecosystem services in the form of soil and nutrient deposits, pest control and pollination. Land use is diverse and is closely linked to the self-sufficiency in fodder, fuel and timber and other biomass requirements; besides, provisions from forests support livelihoods. Subsistence production from agriculture is supported by migration to ensure other financial and livelihood needs. A weak link to larger world is reflected in, relatively speaking, socio-political isolation and absence of market-oriented development. Assets and possessions are limited as a result of low levels of link and low levels of productivity and life choices. The varied diversity of the biota, land and forest-based livelihoods is a result of the type of landuse and production system in place.

5.2 Resilience Characteristics

We observe that while *diversity* of the ecology, social system and production system is limited in SES1, it is moderate to high in SES2; *reserves* are limited in SES1 and social reserves like traditional ecological knowledge is becoming extinct. In SES2, they are available at a moderate level, both in the ecological sphere and social spheres. While the sub-systems and their components are closely connected in the more commercially intense SES,

Table 23: Resilience characteristic of SES 1 and 2

S.No.	Resilience Characteristics and Assumptions	Transformational Traits	
		Kinhola-Dawargaon (SES1)	Kareli (SES2)
1	***Diversity*** – functional and response diversity is crucial for resilience and highly managed ecosystems tends to reduce diversity for efficiency	Being a highly managed ecosystem the species richness and functional diversity is getting limited. • *Patch diversity* of land includes crop land, few orchards and very limited shrub and grass lands. ❖ There is reduction in the natural and cultivated plant and grass species[36]; ❖ land under vegetation has shrunk; so also the species richness of those patches; • crop diversity is affected due to crop shifts and mono cropping tendency; • seed varieties lost and now mainly manufactured seeds are available; • *Response diversity* is also reducing; varieties of local bovine and buffalo species getting reduced; no diversity in water resources (only GW dependent) • *Diversity in livelihood* sources limited, but diversification emerging; low institutional diversity.	Moderately managed forest and agro-ecological system; • *Patch diversity* includes cultivated land, trees and groves, grazing land, forests; • continuity and stability in species of flora and fauna; • *Historical diversity* in natural and cultivated species is still found though possibility of reduced diversity in the future as local species of animals and crops are getting reduced; ❖ local seeds and crops are commonly found; ❖ reduction in traditional crops; ❖ reduction in forest provisions mainly due to weather factors; • *Response diversity* is maintained as there is continuity in the species; • Diverse water resources such as surface water, subsurface seepage, ground water. • *Livelihood diversity* limited but forest provides fall back mechanism; low institutional diversity.

36 We analysed the changes in trees, grass, fruit trees and ornamental varieties at the household level during the past 15 years. The data shows that there is an aggregate 17% reduction in trees along with some species lost, and also 11% loss in fruit trees (as a result of drought also) in SES1; however the fruit varieties are also lost and now mainly sweet lime and pomegranate as commercial crops are grown and a few trees of mango, custard apple, ber and jamun. Grass is mainly Lucerne with no local varieties being cultivated; overall reduction in grass varieties is reported by many. In comparison to this, SES2 has an increase in both tree (timber) and fruit trees especially the natural varieties like Mahua, Char, Bilma, etc., and varieties of local mangoes and other fruits.

S.No.	Resilience Characteristics and Assumptions	Transformational Traits	
		Kinhola-Dawargaon (SES1)	Kareli (SES2)
2	***Reserves*** – ecological, social and economic reserves help in buffers for disturbances and fluctuations.	Ecological reserves are getting reduced; ❖ forest land is being encroached and forest patches getting converted to agricultural lands; ❖ absence of ecological reserve patches like groves; absence of seed banks of local species both crops or non-crops resulting in loss of ecological memory and heirloom/inheritance; ❖ limited fallows and non-cultivated lands ❖ reserves of ground water regime critically low; insufficient buffer against disturbances such as drought; • declining social reserves such as local knowledge and practices due to changed agricultural practices; • socio-economic reserves for many in the form of surplus food grains, • Increased savings and assets mobilization. • Socio-economic reserves at the cost of declining ecological reserves.	• Ecological reserves are more or less stable; ❖ patches of forest and groves sustaining ecological memory; ❖ traditional agriculture helping in preserving genetic memory and heirloom/inheritance (local seeds) and traditional knowledge and practices; ❖ ecological fallows are kept but slowly getting encroached for human survival; ❖ Adequate water reserves and low extraction with buffer for livestock and human consumption in case of disturbances. • Social reserves in the form of traditional knowledge and practices still extant; socio economic reserves limited by subsistence mode of resource extraction.
3	***Modularity –*** Systems with sub-systems and components loosely connected have a higher resilience in the face of disturbances. *A fully connected system can transmit shocks across rapidly.*	Highly connected subsystems and components; ❖ ground water dependent agriculture and livelihood system puts the entire system at risk in case of climatic disturbances; ❖ stressed ecosystem is further impacted by shrinking ecosystem reserves such as common property land resources and common pool ground water resources; ❖ agro-ecological systems (hence livelihoods) and watershed ecosystem or its components like hydrology and water resources is overtly connected; ❖ agriculture is highly connected to commercial inputs and market situations; ❖ Mono-cropping of cotton in large areas even beyond the focal system allows rapid spread of pests and diseases. ❖ Resource use is based on individual rationality and choices; hence lack of social connectedness in this regard; ❖ focal system connected to state agencies in times of distress resulting in political patronage and relief rather than long standing solutions; ❖ communication and connectedness helping in optimizing benefits and also searching for options ***Overall, Less Modularity***	Subsystems and components are moderately connected; ❖ agricultural livelihoods are connected to weather phenomenon but not overtly connected with groundwater; ❖ relative autonomy of livelihoods as there are buffers like forest provisions and migration in the livelihood basket; ❖ agriculture not tightly connected for inputs and markets providing stability, but low levels of production; ❖ adequate and strong vertical connections among the stakeholders on a wider scale; hence strong identity as a larger group; ❖ limited amount of connectedness with the formal systems of governance; ***Overall, Moderate Level Of Modularity***
4	***Tightness of feedback*** – a resilient system would have strong feedback loops which help in recognizing and responding to changes and precariousness of the system.	• In a coupled and highly managed SES such as this, quick responses to feedbacks are essential for not allowing the subsystems or components to move into alternate domains which it lacks • Social networks and institutions helps in this process; however there is lack of such institutional processes for monitoring, generating learning and for collective response. • Individual initiatives are there; stakeholders are aware of the over extraction of resources but no organised system to respond; ❖ *feedbacks* are reinforcing the behaviours such as maximizing ground water use; but, at the same time there are modifications in behaviour patterns such as using technical interventions for water efficiency or changing to less water intensive crops (pomegranate or maize); ❖ *social feedbacks* most often weak in the face of tight ecological feed backs especially during drought; ❖ Mainly, the responses are technology driven individual initiatives; ❖ Social habits are also altered such as moving into acquiring higher education and widening the scope of livelihoods.	• Moderately influenced ecological system and close knit community relations provide opportunities for appropriate frameworks for feedback responses. • Presently, institutional frameworks (introduced as part of the project) are discontinued and hence also the process for monitoring and generating learning for collective response. • There are no strong traits of reinforcing behaviour patterns even though positive feedbacks occur in terms of increased water or opportunities for irrigated agriculture; ❖ the values determining the way of life are not very accumulative or acquisitive in nature; hence chances of modifying behaviours in face of negative feed backs is high; ❖ *Social feedbacks* are moderately tight; in case of strong *ecological feedbacks* which was evident as the response to changing forest provisions made the community think of improving the forest cover.

S.No.	Resilience Characteristics and Assumptions	Transformational Traits	
		Kinhola-Dawargaon (SES1)	Kareli (SES2)
5 are	***Openness*** – extremely open and too closed a system can hinder resilience.	• Access to resources and use rights, especially ground water, is very open ❖ hence in the stage of over exploitation, the production system is open to exogenous factors such as high inputs and market variability; • the social system is open for innovations and experimentation in relation to production and livelihoods	• Moderately closed system both economically and socially; ❖ access to resources and user rights open but influenced by a system of fairness across the stakeholders; ❖ production and local economy is very closed with few links and openness to external factors; • The social system is fairly closed and adoption of innovations and changes are very slow process.
6	***Social capital and governance mechanism*** – social networks, institutions, trust and governance structures impacts resilience traits in the system. *A resilient system would promote those*	• Social networks are weak; • informal structures of relationships exist; • the institutional arrangements introduced as part of the project cease to exist; • leadership is not inclusive; • new institutions that have emerged are also in a project mode to facilitate accessing development resources; • information sharing across stakeholders is not uniform but selective, based on preferences of the leadership; • the peripheral groups feel excluded; • the property rights of the most valued ecosystem service like groundwater, is highly private and access rights are land ownership bound; • formal institutions are not flexible to facilitate changes; • no cascading institutional arrangements; • no rules regarding resource utilization or maintenance of the resources; • Overall limited *social capital* and community governance structures. • *formal constitutional* and informal community organizations are not tuned for adaptive management of ecosystem and social interaction.	• Informal traditional networks are strong; • the leadership is inclusive and socially legitimized; • no subset of networks or groups feel excluded from resources or the decision process; • Institutional arrangements as part of the intervention weakening; • right mix of property regimes and access rights whether it is water or forest produce; however no institutional codes on access and extraction except for common forest produce; • the small demographic size of the focal system and the uniformity of the stakeholders creates a manageable environment; • *Formal institutions* of governance are weakly linked to the traditional structures exercising limited influence; the people seeformal structures as exploitative and distrust exists. • an inclusive social space and leadership and basic trust and social networks could facilitate adaptive management of ecosystems and social interactions.
7	***Ecosystem services*** – a resilient system supplies various bundles of ecosystem services that are beneficial to the stakeholders as well as to the ecological system itself.	• ecosystem services such as ❖ provision of ground water; ❖ crop production; and ❖ regulatory functions like erosion control, clean water, are highly valued and watershed intervention have contributed to most of these; • however, non-crop biomass provisions are very limited; • While the ecosystems functions and services for the stakeholders have improved, its functions to natural capital, i.e., services that sustain ecosystems services, are not taken care off due to command and control management and over extraction of services. • There are also elements of conflict for example ❖ the control of soil erosion is valued but the natural soil qualities and productivity is being lost due to excessive use of chemicals and pesticides; ❖ Agricultural production system is in conflict with ecosystem resilience and will create problems for ground water in the long run. • A systems perspective is lacking in the ecosystem services domain; ❖ Pest regulation through high use of pesticides is affecting other ecosystem services of natural pest control and pollination. • In short, the provisioning for increased production is achieved, but the ecosystem health is reaching a state of precariousness.	• ecosystem services such as surface and ground water, forest provisions and non-crop biomass provisions are highly valued; the ecosystem services for social, cultural and natural needs are equally valued. • the production system is in tune with the natural systems and provisions and very little alterations in achieving production efficiency. • other regulating functions such as erosion control, pest and disease control of crops, pollination functions are valued and not interfered with; • spiritual values are ingrained in the social and ecological interactions – wild food, fuel and fodder, plant and crop genetic resources are highly valued and preserved; • overall, there is a balance in the ecosystem services for subsistence and sustenance of the ecosystem habitat.

there is a certain amount of *modularity* in the other thus making it less vulnerable to external shocks and stresses. In both the SESs, the feedback response is found to be weak. While the thresholds requiring feedback response of the social system are visible in SES1, SES2 has not reached threshold in ecological components like ground water. In SES1, there is a realization of the thresholds being reached, but the solutions are sought in a technical fix; while some of those fixes can add value (eg. drip irrigation) some are purely mal-adaptation like the well deepening or horizontal bore wells or the farm ponds as storage ponds.

The *ecosystem services* have improved in both the topologies. However, in SES1, they are largely valued only in terms of their utility for enhancing production and generating income; the approach of SES2 values these services and tries to balance human, livelihood, cultural and spiritual and ecological needs.

While the *social capital and governance* structures that run the SESs are not very strong and institutional redundancy rather low, SES2 scores over SES1 as traditional structures still command respect.

Thus, overall, we see two distinct trajectories in the two topologies influenced by various factors working at different scales. While the socio-economic and livelihood resilience is improving in both, it could be at the cost of the ecosystem resilience in one (i.e., SES1), as it is located already in a stressed ecosystem.

This brings us to the larger question of whether watershed development could be equated with adaptive co-management as elaborated by resilience thinkers and practitioners. An adaptive co-management approach for managing resilience would value diversity, reserves, modularity, overlapping governance mechanism and so on. Most often WSD with its overemphasis on production enhancement fails to factor the links across the sub-systems and variables and possibility of systems flipping into undesirable shifts. The decreasing diversity and competition to extract ground water in SES1 is such a case in point. This is because a command and control approach based on maximizing economic efficiency is adopted unlike as in SES2 where an approach which is more inclusive of the views and interest of the various stakeholders and attempts to build on ecological variability and system interactions. A conventional watershed development approach (business as usual packages of practices) that looks only at efficiency would fall short of qualifying for the criteria of adaptive co-management, as elaborated in the literature.[37]

The development discourse in general and watershed development in particular, have highlighted the need ensuring sustainability, inclusiveness and equity in the development process and outcomes. Ecosystem resilience is a pre-condition for sustainable growth; however, a sustainable resilient ecosystem is a challenge. Resilience theorists factor sustainability in their discussions (Folke *et al.* 2002) and it is important that it be brought into practice. Sustainability is a desired end having a normative and moral perspective while resilience may not be so. What is resilient today may not be sustainable in the long run if the 'desirable', as required for sustainability is not built into the resilience approach. In sustainability terms, a "resilient socio-ecological system in a 'desirable' state has a greater capacity to continue providing us with the goods and services that support our quality of life while being subjected to a variety of shocks" (Walker and Salt, 2006, p. 32). What is desirable is based on human choice and socially determined. In short, if sustainability principles are not factored into the resilience analysis, a current resilient system may become non-resilient in the long run. RA introduces the concept of "resilience based stewardship" as the management strategy for SES which brings it closer to the sustainability principles. In the context of resilience-based stewardship, the overarching goal is to '*sustain the capacity of the SES to provide benefits to society*'. The questions of which benefits and to whom the benefits flow are fundamentally important and demand effective stakeholder participation (workbook p. 47).

37 It is important to note that there are very few examples (package of practices) of facilitating adaptive co-management in highly managed socio-ecological systems; most of the items on the list of strategies of adaptive co-management or adaptive stewardship (RA 2010 p. 37 and 47) are a set of suggestions. Some of those strategies are what is already being done under on-going watershed development such as the approach like 'learning by doing'. The limited time bound project mode of WSD, as with other developmental interventions, however limits the scope of such strategies as the continuity of the process falters once agencies and resources are withdrawn.

Section 6: Building Socio-Ecological Resilience in Watershed Programs: Learning and Considerations

We analyse this issue from three inter-related components of watershed development, namely, technology, processes and institutions. Policies and programmes need to be fine-tuned in relation to these aspects to make watersheds more resilient to variability and unexpected changes. The recommendations draw some insights from adaptive management of SES as suggested in some of the writings on resilience of socio-ecological systems as well on insights drawn from the study. While the resilience characteristics and strategies would vary from focal system to focal system, it is important to have a set of principles which are flexible and have the potential to be operationalized within contextual specifics.

6.1 Technology

- Technological interventions should be aimed at helping to adapt to changes rather than focusing only on modifying the ecological processes. Innovations and learning-by-doing strategies need to be the hallmark of the technology.
- Technological inputs should follow a systems' approach where interactions and outcome of various sub-systems and its components are taken into consideration. Technology should promote diversity, whether it is in land use, cropping and agricultural practices, livestock system biodiversity, etc.
- A right mix of science-based and predictable approaches and local knowledge-based experimental approaches are required instead of a top-down menu of interventions.
- Models and scenarios based on multiple technology and policy options need to be promoted.
- The specific impact of technologies not just at the focal level but also at other scales needs to be considered as SESs are linked at spatial and temporal scales.
- Technology could ensure short-term or long-term benefits but still be maladaptive. This aspect needs to be assessed before promoting various technologies.
- Technologies alone may not be the solution for certain problems; solutions may be in the management or institutional realm. An adaptive management approach should factor all options available and technological solutions should be sought where necessary. This is important as there is an increasing trend to fix the irrigation water consumption through technological interventions such as drip and so on. Alternative management practices are not sought and linear solutions are explored.

6.2 Institutional and Governance Mechanisms

- Institutions should be crafted around challenges and emerging needs rather than to only manage the efficiency of an intervention. This means institutions should be designed for adaptation to environmental changes and be flexible to address emerging needs.
- The emphasis and objectives of adaptive institutions should be on searching solutions to vulnerability and facilitating adaptation rather than achieving fixed targets; it does not mean that accountability is not factored-accountability should be judged on finding innovative solutions to anticipated as well as sudden changes.
- Institutions with overlapping functions are required; institutional redundancy needs to be promoted. Solutions may be found at different levels and failure of one does not handicap the entire system. Institutional diversity ensures innovations and could tackle vulnerability effectively. This would also help in not concentrating decision making in the hands of a few.

- Local institutions need to be linked to formal structures and structures beyond the focal scale; some redundancy between state and social institutions is necessary for building resilience (Rock feller Review, p 25). The state institutions need to work with endogenous institutions rather than by passing them or replacing them in the name of achieving efficiency
- While promoting social networks and local leadership, the issue of inclusiveness of such agencies and actors needs to be assessed; social exclusion can hinder resilience outcome for the focal system and also for the excluded stakeholders
- A right mix of property regimes need to be promoted. Rights are to be ensured and clearly defined with a pro-poor bias (who are the most vulnerable) and in line with the needs of the community to pursue livelihoods and socio-economic well-being
- The feedback response of related institutions needs to be strengthened; positive responses to feedbacks and behavioural changes and institutional innovations need to be incentivised, promoted and subsidized

6.3 Processes

- Planning with a focus on the linkages, interactions and outcomes among various sub-systems and their components in the watersheds: this would include identifying the key sub-systems and variables that drive the system components, the threshold levels, the feedback system and the conditions under which changes occur, as also identifying the stage of development (adaptive cycle). The interactions of the social and ecological system would be the focus.
- Such a planning exercise should take into account the interactions of the system at a larger spatial and temporal scale. This is crucial, as a watershed is a linked system. The spatial scale could be a larger watershed of a few thousand hectares[38] and temporal scale could be of a few decades as that would help in analysing the changes in society-resource interactions and also would help in documenting the changes in diversity, response to disturbances, threshold levels, social and ecological memory and so on.
- Planning and implementation needs to be dynamic and flexible taking into account the changes in feedbacks, new learning emerging from experiences and the system's dynamics. The planning tools need to have the right mix of technological aids including spatial images and GIS tools, hydro-geological information, participatory land use planning tools, social and ethnographic methods, simple models projecting scenarios etc.
- Facilitating collective actions, building networks and institutions, institutionalizing community monitoring and learning should be the approach rather than the conventional approach of stakeholder consultation and participation.
- Adaptive management approaches and their proponents highlight that small scale disturbances are intrinsic to the system and should be dealt with in a timely manner rather than allowing them to cascade into larger disturbances engulfing the entire focal system or beyond that. Citing a large number of authors, a review report by UFZ suggests that the aim of adaptive management is to prevent the build-up of large-scale crisis. This type of management is termed as "back loop management" since it indirectly takes into consideration the "release-reorganization" phases of the adaptive cycle. A management approach that suppresses disturbance is regarded as unsustainable. With unexpected changes as a result of climate variations, such an approach would be helpful in making watershed management projects more resilient.
- However, to allow and manage small disturbance would require vigilant and capable community and leaders; therefore the type of social capital promoted and the systems to build its capability would be of utmost importance. Instead of a conventional Capacity Building approach, the system should move into 'learning-by-doing and experimentations' mode.

38 It is important to note that the present unit of watershed implementation under the national Programme (IWMP) is also around 4000-5000 ha. However the planning and implementation is done at small units without looking into the scale linkages.

Section 7: Conclusion

With climate change expected to have far reaching implications on agriculture and rural livelihoods, there is an urgent need to undertake measures that reduce vulnerability, enhance resilience and build adaptive capacities of communities to climate-induced shocks.

This study, together with others, confirms that community-led watershed development has the potential to make a significant contribution towards achieving these outcomes. WSD contributes positively to enhancing the resilience of ecosystems as well as the subsisting social and livelihood sub-systems. However, if this is to be sustained in the longer term, then the social sub-system needs to pursue innovative technical, governance and institutional strategies that would help manage the ecosystem in a manner that is adaptive and sustainable.

In particular, there is an urgent need to look at and re-organise the way natural resources are managed. As we have seen in this study, one of the successfully developed watershed SESs has adopted a resource use and production system that, while enhancing resilience in the short run, is clearly unsustainable, resource depleting, maladaptive and economically ruinous in the longer term. This paradigm largely ignores the system feedbacks, signals and links which are so crucial for changing or introducing new behaviour patterns vis-a-vis resource use. Institutional and governance responses to system feedbacks together with technological innovations are essential for realising and sustaining the desirable and preventing socio-ecological systems from being trapped in a perpetual cycle of vulnerability, bad subsidies and maladaptive coping strategies.

If watershed development is to live up to its promise, there is a need to bring about changes in the way 'the dominant package of practices'-technological, institutional and operational processes-are conceptualised, organised and implemented in policy and practice.

By going beyond the project mode, that is, by empowering communities to sustainably manage their regenerated ecosystems and its services and engage with relevant resource agencies across sectors and levels on a continued basis, watershed development as a programmatic intervention can become an effective strategy for enhancing resilience and building up the capacities of communities to adapt to climate variability. Lessons gained from adaptively managed socio-ecological systems can provide important clues on how this can be progressed and realised.

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About WOTR

Established in 1993, WOTR is a non-profit that engages at the intersection of practice, knowledge and policy across scales and in collaboration with stakeholders from across sectors. Headquartered in Pune, WOTR has supported and carried out developmental work in over 3500 villages across 7 states of India.

WOTR assists rural communities to assess their vulnerabilities to climate and non-climatic risks. It organizes them in a socially and gender inclusive manner to help themselves out of poverty by regenerating their ecosystems in a holistic and integrated manner, conserving and optimising resource use, especially water, and undertaking climate smart sustainable livelihoods.

Being a Learning Organisation, WOTR undertakes applied research and closely engages with institutional and governance actors so that insights and good practices derived from ground experience contribute to shaping enabling policies and effective programs. With a view to up-scale successful interventions, WOTR develops pedagogies for implementation and organises a variety of knowledge sharing and capacity building events for stakeholders across the civil society, developmental and governance spaces, from India and other countries.

About SUGAP

The Scaling Up Good Adaptation Practices (SUGAP) project is a partnership between the Swiss Agency for Development and Cooperation (SDC), the Watershed Organisation Trust (WOTR) and the World Resources Institute (WRI) to further the development of climate resilience in semi-arid regions of India. The partnership conducts research, convening, and outreach to promote climate change adaptation policies and funding programs at national and international levels.

This paper is the second of a series of three case studies designed to highlight lessons learned from SDC and the National Bank for Agriculture and Rural Development (NABARD) supported Climate Change Adaptation Project implemented by WOTR.

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