



## Staging stewards of agro-ecosystems in the ecosystem services framework

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### ARTICLE INFO

#### Keywords:

ES valuation  
Environmental behavior  
Landscape stewardship  
Livelihood  
Social-ecological system

### ABSTRACT

Ecosystems provide services which are central to human well-being. However, they are undergoing rapid change due to human interferences. In times of globalization and cosmopolitan citizenship, boundaries (*fringe*) between rural and urban landscapes are blurring which make agro-ecosystems vulnerable. Critical understanding of societal transformation driving ecological change across different scales, especially fringe landscapes is necessary for operationalizing a holistic growth model in developing nations. Ecosystem services provided by agro-ecosystems and their value to stakeholders are often overlooked in the conservation and resource management actions in India. An evaluation framework was designed, considering stakeholders with *direct* and *indirect* access to services for agro-ecosystem management. Users' demand for ecosystem services and their environmental behavior was assessed, using a combination of ES valuation tools and methods. Results highlight that *direct users* are the potential landscape stewards of agro-ecosystems. Being custodians of the ecosystem, there is a need for engagement of direct users in the *present* management interventions to ensure sustainable social-ecological systems in *future*. The study puts forward that the application of landscape stewardship concept can contribute to sustainable management of ecosystems, while considering the nested multi-scale dynamics of social-ecological systems in developing nations.

### 1. Introduction

Humans directly and/or indirectly manage ecosystems to maximize the provision of ecosystem services that underpin their survival, livelihood and economic growth (Millennium Ecosystem Assessment, MA, 2005). Global demand for food and fuel puts undue pressure on natural ecosystems, augmenting their subsequent conversion to agro-ecosystems (MA, 2005; Mertz et al., 2007). Agro-ecosystems cover over a third of global land area (Garbach et al., 2014). They are intensively managed to optimize the provisioning of food, fibre, other goods, and energy, for which they depend upon a network of regulating and supporting services (carbon sequestration, pollination, pest control, soil fertility, etc.), as inputs to production (MA, 2005; National Research Council, 2005; Zhang et al., 2007). In times of globalization and cosmopolitan citizenship, boundaries (*fringe*) between rural and urban landscapes are blurring. Rapid land-use changes are driving a parallel trend of unsustainable rural to urban transformation and migration (Pauleit et al., 2010). Such transformations change the intrinsic structure and organization of rural landscapes and make agro-ecosystems vulnerable. However, the population in these rural and fringe landscapes depends majorly on local ecosystem services, ES for their

livelihoods, which are also in focus for sizeable developments and investments. The inclusion of ES contributed by agro-ecosystems in management actions is crucial; otherwise, it may aggravate poverty, environmental, and food security issues.

Existing ES valuation frameworks seldom holistically evaluate potential trade-offs and synergies among ES in rural and fringe landscapes. ES valuation studies have often dealt with well-being issues; however, *impacts* (drivers) on ES were mostly described (MA, 2005; Suich et al., 2015). A few empirical researches examined the relationships at the micro-level, but inadequately determined stakeholders that were 'actually' benefitted by ES (Sangha et al., 2015, 2017). Certainly, questions remain unanswered on the links between ES and drivers, and effect of these linkages on different aspects of well-being (Fisher et al., 2013, 2014). Social differentiation and other associated factors, including relative importance of the interactions to household, livelihood and well-being also need to be considered to holistically understand these linkages in social-ecological systems, SESs (Sangha et al., 2015, 2017). Anderies et al. (2004) suggested that the structure of SESs is best understood in terms of the relationships between resources, resource-users and governance systems. Differential *nature* and *purpose of access* to resources must be accounted to empirically understand these *linkages*

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(Mehring et al., 2018; Suich et al., 2015). Determining these linkages in agro-ecosystems may help in identification of potential gaps to address and guide future research (Liebenow et al., 2012).

Agro-ecosystems are a prime component of rural living and urban well-being in India, but remain understudied in terms of ES (Costanza, 2008; Porter et al., 2009; Sinare et al., 2016). Rural inhabitants depend both directly and indirectly on agro-ecosystems. Alterations in the services provided by agro-ecosystems may drastically affect rural inhabitants who directly depend on agro-ecosystems -on varying scales-for survival and livelihood (*direct users*). While a few rural and urban inhabitants have the choice of using ES from a number of rural and fringe landscapes since they aren't directly dependent on specific agro-ecosystems (*indirect users*). Deeper understanding of multi-dimensional dependence of direct and indirect users on agro-ecosystems can guide management interventions (Sinare et al., 2016). Valuing and quantifying this dependence on ES (demand) of key stakeholders (direct and indirect users), there is a need to identify potential landscape stewards of agro-ecosystems, i.e. better custodians of the ecosystem (Boerema et al., 2016; Milder et al., 2014; Plieninger et al., 2015; Sang and Tviert, 2013). *Landscape stewardship* has lately gained research attention as an effective tool to tackle issues of rural poverty and food security, especially in developing nations (Folke et al., 2009; Raymond et al., 2013). The concept of landscape stewardship centers on fringe landscapes, exposed to multiple societal demands for infrastructure, urbanization, agricultural land-uses, and/or recreation. It informs place-based values which affect people's perception and attitudes towards conservation and planning (Lokocz et al., 2011; Plieninger et al., 2015).

We hypothesize that local inhabitants, i.e. direct users are not only the stakeholders 'affecting' agro-ecosystems, however they are potential 'stewards' of the system. In the present context, landscape stewardship is defined as "efforts to ensure food production, biodiversity and ecosystem conservation, cultural heritage preservation, as well as human well-being, than mere maximization of an individual ecosystem good or service" (Milder et al., 2014; Plieninger et al., 2015; Sang and Tviert, 2013). The study aims to (i) determine and quantify the dependence of users on ES, (ii) analyze the impact of urban influences on the users' attitude towards ES, (iii) identify the potential landscape stewards in an agro-ecosystem, and (iv) establish the linkages between ES and well-being in an SES in a holistic and instrumental frame. Results may highlight the barriers to and incentives for attaining landscape stewardship in an agro-ecosystem, which could act as an important input for staging agro-ecosystem stewards in the ES framework.

## 2. Methods

### 2.1. Evaluation framework

To advance understanding on the linkages between ES and well-being, an evaluation framework for agro-ecosystem management was conceptualized (Fig. 1), fusing insights from MA (2005) and SES researches (Díaz et al., 2011; Fisher et al., 2014; Ostrom, 2009). The framework was conceptualized, taking India- a developing nation into consideration, characterized by subsistence and local dependence on ES (see Mehring et al., 2018; Sangha et al., 2015, 2017). Although the framework is for agro-ecosystems, applications are also of relevance to transitional landscapes (Elmqvist, 2011; Ernstson et al., 2010).

### 2.2. Study area

In India, impact of agriculture on the socio-economic fabric is significant as it supports livelihood of 60% of its population. Agriculture contributes around 18.5% to the nation's GDP. The state of Uttar Pradesh, India plays a key role in this contribution as it has the highest number of farm holdings and produces one-fifth of the total food grains in the country. Agriculture contributes about 33% to the total income of Uttar Pradesh (District Agriculture Plan, Baghpat). Agro-ecosystems in

Uttar Pradesh are recently experiencing major transformations due to urban-rural transitions.

Four fringe villages, viz. Doghat, Tikri, Daha, and Nirpura were identified in Baghpat, Uttar Pradesh, India (Fig. 2; Table 1). Total geographical area of Baghpat is 13.33 lakh hectares, supporting a population of 11.64 lakh; 42.7% of the population consists of farmers, of which 87.6% are small and marginal farmers. Number of rural cottage industry is 326, while the district also supports livestock, milk production, dairy farming, and poultry. We chose this study area because these interface villages are agriculture-based, and are under the influence of metropolitan set-ups viz. Delhi, an urban agglomeration, and other peripheral cities viz. Meerut, Muzaffarnagar, Panipat, and Sonapat. Baghpat is a harmonious mixture of the social-cultural and socio-economic attributes of Delhi, Haryana, and Uttar Pradesh. This unique setting gives us an opportunity to study the users' demand and their attitude towards ES in a dynamic, fringe landscape (Boerema et al., 2016; Pauleit et al., 2010).

### 2.3. Data collection and analyses

As per the designed evaluation framework, a stage-based study was conducted; each stage having specific aim(s), tools and methods, and inferences (for details, see Table 2). 28 ES were identified for the study, i.e. 16 provisioning services- gas, oil, wood and coal, surface water, ground water, vegetation, soil, land, agro-forests, fauna, metals and ores, potable water, food, fodder and fibre, raw material (others), medicine and 12 regulating and supporting services- climate regulation, water purification, natural pest control, composting, pollination, soil retention, habitat (biodiversity), crop diversity, water provision, nutrient cycling, soil fertility and structure, energy and fuel (others). Two major stakeholder groups, based on their *nature of access* to ES were identified as *direct* and *indirect* users (Fig. 3; Table 3). 196 users (respondents) were interviewed using structured and semi-structured questionnaires, along with focus-group discussions and field observations during field survey (see tenets of the questionnaire in Table 2). Direct users ( $n = 109$ ), comprised of those involved in production viz. farm owners and laborers, blacksmiths and welders (*lohaar*), potters (*kumhaar*), carpenters (*badhai*), kiln factory owners and laborers, jaggery factory owners and laborers, and dairy farmers. Indirect users ( $n = 87$ ) included the ones not involved in production, however, consuming ES viz. house-wives, students, shopkeepers, vendors, and businessmen, etc. On the basis of occupation, direct users were further grouped into *micro-entrepreneurs* ( $n = 36$ ), *macro-entrepreneurs (farmers)* ( $n = 56$ ), and *macro-entrepreneurs (others)* ( $n = 17$ ) (Fig. 3). Micro-entrepreneurs comprised of traditional craftsmen, artisans like blacksmiths and welders (*lohaar*), potters (*kumhaar*), and carpenters (*badhai*), macro-entrepreneurs (farmers) included farm owners and laborers, while macro-entrepreneurs (others) included kiln factory owners and laborers, jaggery factory owners and laborers, and dairy farmers. Users' demand for ecosystem services and their environmental behavior was assessed, using a combination of ES valuation tools and methods (see Table 2). A detailed analysis based on the users' *purpose of access* to ES was conducted. Direct users' demand for *production* ( $n = 109$ ), while direct as well as indirect users' demand for *consumption* ( $n = 196$ ) was estimated. Differences in users' demand for ES were tested using t-test (at  $p < 0.05$ ). The effect of socio-economic variables on the users' demand for ES was also tested using one-way ANOVA (Tukey's HSD test), (SPSS 16.0, SPSS Inc. 2007, Chicago, USA).

## 3. Results

Of the 196 users, 46 belonged to Doghat, 51 to Tikri, 50 to Daha, and 49 were from Nirpura. In total, there were 157 male and 39 female respondents; proportionately more males (80.11%) were interviewed than females (19.89%) due to the working population comprising mostly of males. Females in the area are largely home-based (home-

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