Ecosystem services approach for revitalizing agriculture in India

M. Manjula, L. Venkatachalam, P. Mukhopadhyay and Lalit Kumar*

Agricultural landscapes referred to as 'agro-ecosystems' provide both marketable and non-marketable ecosystem services. The ability of agro-ecosystems to provide ecosystem services is limited by the nature of production systems and production method. Promotion of input-intensive production systems results in short-term productivity gains along with long-term ecological and environmental losses. India's agriculture suffers from various ecological problems such as soil pollution, over-exploitation of groundwater and loss of biodiversity. Policy measures aimed at improving agriculture should shift from a purely 'productivity enhancement' objective towards promotion of ecologically sustainable pro-environmental agricultural production (PAP) practices to realize the goal of 'productivity in perpetuity'. This article examines the feasibility of 'nudges and incentives' in payment for ecosystem services/agri-environmental schemes (PES/AES) type schemes in India which could be a possible policy solution. It could nudge farmers to PAP practices and would be fiscally feasible even for individual states to adopt in a federal system of governance.

Keywords: Agro-ecosystems, evergreen revolution, payment for ecosystem services, pro-environmental agricultural production.

AGRICULTURE is classified as an ecosystem (agro-ecosystem) that both consumes and provides valuable ecosystem services[1]. Agro-ecosystems are conventionally designed to provide valuable provisioning services like food, fibre and fuel that are marketable in nature. In addition to marketable provisioning services, agricultural activities generate non-market ecosystem services that are utilized by innumerable production and consumption activities in the economy[2]. The non-market services include regulating, supporting and cultural services such as climate regulation, water purification, biodiversity protection, pollination services, regulation of surface water flow, maintaining groundwater level and waste recycling[3,4]. The ability of the agro-ecosystems to provide socially beneficial non-market ecosystem services is determined by the nature of production systems as well as the methods of production[5,6]. In order to maximize social welfare, agricultural policies should aim at encouraging farmers to expand the area under ecologically sustainable pro-environmental agricultural production (PAP) practices.

A purely productivity-based approach followed in conventional agricultural policies in developing countries like India has resulted in input-intensive, environmentally exploitative agricultural production systems[7]. The resultant 'agricultural stress' manifested as unchecked soil erosion, tropical deforestation, water deficits, drought, desertification, loss of biodiversity and landlessness is more acutely experienced in countries like India with high population density[8]. Conventional farm practices in India are known for indiscriminate use of chemical fertilizers and pesticides, and the country accounts for about 51% of the total global emissions from agriculture[9]. Increased withdrawal of water for irrigation has resulted in a drop in groundwater tables, and groundwater overexploitation poses a major threat to India's food and livelihood security in the coming years[10].

Business-as-usual approaches to increasing agricultural output through intensive ecologically unsustainable agricultural practices will only result in exacerbating the contribution of agriculture to global warming. A shift in policy thrust from 'productivity enhancement' to ecological sustainability would help attain 'evergreen revolution' with the goal of 'productivity in perpetuity without accompanying ecological harm'[11]. Achieving 'productivity in perpetuity' would entail promotion of an agricultural production system that avoids enormous social costs in agriculture. Such a production system would optimize productivity through conserving natural resources sustainably, enhancing soil, land and water quality, and protecting and conserving biodiversity[12]. Agricultural production systems ranging from those that are purely

M. Manjula is in the M. S. Swaminathan Research Foundation, Chennai 600 113, India; L. Venkatachalam is in the Madras Institute of Development Studies, Chennai 600 020, India; P. Mukhopadhyay is in the Goa University, Goa 403 206, India and Lalit Kumar is in the Bhim Rao Ambedkar College, Delhi University, Delhi 110 094, India.
*For correspondence. (e-mail: mmanjumenon@gmail.com)

based on traditional practices to the ones with varying levels of traditional and modern scientific practices have been advocated to achieve a shift from 'pure productivity enhancing conventional approach' to 'ecologically sustainable PAP practices'. Some of the pro-environmental production pathways include organic agriculture, sustainable agriculture and eco-agriculture[12]. Organic agriculture is a holistic production system which uses agronomic, biological and mechanical methods in place of synthetic materials to fulfill specific functions of the production systems[13,14]. Organic agriculture is based on the four principles of health, ecology, fairness and care[15]. Sustainable agriculture relies on principles of integrated pest management and integrated nutrient management with accommodation of minimal use of chemical inputs. Sustainable agriculture is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable[16]. Eco-agriculture is based on the principle of enhancement of wild biodiversity and its utility in agriculture for attaining higher production and sustainability. Eco-agriculture manages natural areas and agricultural landscapes in complementary ways and results in production systems where there are no trade-offs among conservation, food production and livelihoods[17]. Other means of shifting to a PAP practice model are through adoption of locally suitable integrated farming systems models, mutually reinforcing and complementing intercropping and mixed cropping models, shift in cropping pattern and agronomic practices aimed at reducing water stress, and exploiting the potential of beneficial microorganisms for improving agricultural productivity through use of microorganism-based biofertilizers and biopesticides[18,19].

However, a shift from conventional to PAP practices has its own challenges. These include lack of awareness on environmentally safe agriculture practices, lack of access to easy-to-use and affordable eco-technologies, lack of market demand, and long gestation period to achieve the optimum yield and revenue from farming. The high cost of environmentally safe alternative technologies may also act as a deterrent in farmers' willingness to adopt them, despite large social benefits. As a result, seemingly 'rational' farmers tend to use cheaper alternatives like chemical-intensive nutrient and pest management practices that are highly subsidized but environmentally detrimental. The practice of stubble burning in paddy fields by farmers in the Indian states like Punjab and Haryana, which causes severe air pollution in the northern part of the country, is one such example. Farmers who are rational may need to be incentivized to adopt PAP practices.

The policy challenge lies in finding the right instrument to incentivize or nudge farmers to adopt PAP practices. Effecting behavioural change is contingent upon the nature and size of the incentives and disincentives. Mechanisms like 'payment for ecosystem services' (PES) and 'agri-environmental schemes' (AES) provide a Pigouvian framework for justifying subsidies[20,21]. The extent of the payment needs to equate the marginal cost of adoption to the marginal benefit from PAP practices. Incentivizing farmers through adequate monetary compensation could be an effective way to encourage them to shift to PAP practices that maximize private benefits at zero social cost[22]. This would enhance the ecosystem base and reduce the environmental damages from conventional agricultural practices. Similarly, a model for implementing 'PES for water' at low transaction cost among farmers has been proposed in the Cauvery river basin in Karnataka, India[23]. The PES, in addition to rewarding farmers for their conservation efforts facilitating clean water flow downstream, was also outlined to be significant in instilling water-use discipline and improving system efficiency.

Currently, the policy environment in India is conducive to the introduction of instruments in line with AES, as India's National Environment Policy 2006 proposed to introduce market-based instruments (MBIs) for environmental management[24]. Under the WTO regulations, such MBIs qualify as a green-box subsidy measure for sustainable agriculture. This article highlights how such an incentive mechanism can be introduced in India's agriculture sector at the state and regional levels.

Materials and methods

There are no country-level data available on ecosystem services from agro-ecosystems. Therefore, we relied on the values available from Economics of Ecosystems and Biodiversity (TEEB) valuation database[2]. The international values were suitably adjusted to Indian prices with an appropriate exchange rate and GDP deflated to estimate current local values.

Data on state-wise total cultivable land were taken from ref. 25. The information on agricultural development, which includes budgetary allocation for agriculture and allied activities, irrigation, relief on account of natural calamities was taken from ref. 26.

We first extracted the value of non-market agro-ecosystem services. Next, we estimated the total potential PES to incentivise adoption of PAP system across regions. Then we examined the budgetary requirement for implementing PES across regions.

Estimation of non-market ecosystem services

The TEEB database provides item-wise estimates of ecosystem services from agro-ecosystems. In order to arrive at the value of non-market agro-ecosystem services, the values attributable to provisioning and recreational services were subtracted from the total economic value (TEV) from agro-ecosystems. Since provisioning and

recreational services are traded and have a market value, subtracting their value avoids double-counting. The TEEB database provides per hectare values in US dollar terms for the year 2007. We derived values for India by multiplying these with purchasing power parity (PPP) 2017 dollar–rupee exchange rate (Rs 17.76 to US$ 1) in order to make them comparable to other values taken for the same year in rest of the analysis.

Estimation of total potential PES

The total potential PES was estimated by multiplying the annual value of non-market ecosystem services per hectare by the total cultivable land available in different states of India. The analysis was carried out across geographical regions, namely north, south, east and west, and major states across regions were included. Haryana, Punjab, Rajasthan and Uttar Pradesh were included as part of the northern region. Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Telangana made up the southern region. The eastern region included Bihar, Jharkhand, Odisha, West Bengal and states of the North East, viz. Assam and Arunachal Pradesh. Gujarat, Maharashtra, Madhya Pradesh, Chhattisgarh and Goa were classified under the western region. The total cultivable land of individual states falling within a region was summed up to arrive at the total cultivable land in the respective region. It is to be noted that the states included in the regional analysis are not exhaustive. Therefore, this aggregation of total cultivable land obtained through a summation across regions for the year 2017, would be less than the total cultivable land of India in the same year.

Budgetary requirement for implementing PES

The budgetary allocation for agricultural development in 2016–17 was available from RBIs state budget reports. Region-wise estimates were derived by totalling up for state allocations in each region. We excluded the central outlay on agriculture, because these amounts are not under the control of the states. This budgetary allocation could potentially be channelled to finance PES-type mechanism for farmers adopting PAP practices.

Assigning PES values

The literature suggests that farmers using PAP practices potentially produce: (a) increased carbon sequestration in soil, (b) reduced water usage and (c) lower toxic residuals in soil[11]. Farmers currently practising conventional agriculture could be nudged to adopt PAP practices that lead to one or more of the above three outcomes (a)–(c). They may choose one of three possible options: (i) high adoption (HA, where farmers undertake practices that result in all the three desirable outcomes); (ii) medium adoption (MA, where farmers undertake practices that result in any two of the three desirable outcomes), and (iii) low adoption (LA, where farmers undertake practices that result in any one of the three desirable outcomes). Based on the extent of adoption the amount of PES could be determined. A five-year transition period is considered for a complete transition to HA, MA or LA[26]. If farmers choose HA (all three outcomes), then the entire potential PES is paid to them. This amount is calculated by multiplying the total cultivable land (ha) across all states by the annual PES amount estimated per hectare. If farmers choose MA (any two outcomes), we propose that 70% of the potential PES amount should be paid. And, if they choose LA (any one outcome), we propose that 35% of the potential PES amount should be paid. This allows us to estimate the budgetary requirements for implementing PES under three different outcomes. As a five-year transition period is considered for a complete transition to HA, MA or LA, the annual PES to be paid out is one-fifth of the PES amount proposed for each of the scenarios.

Results

The TEV of the various agro-ecosystem services at the global level was estimated to be US$ 3839 per year per hectare at 2007 prices[2]. This value was made comparable in Indian 2017 prices by converting the dollar to rupee values (using an exchange rate of Rs 17.76 per 1 US$). This gives us a TEV of INR 0.07 m/ha/year (in 2017), under *ceteris paribus* assumptions. The size of the PES to effect a transition to PAP practices should be equivalent to the value of the non-market ecosystem services generated from agro-ecosystems. The value of the non-marketed ecosystem goods and services was derived by deducting the value of the traded provisioning and recreational items, totalling to INR 0.026 million (USD 1477) from the TEV (INR 0.07 million, USD 3839), and that gave us a figure of INR 0.042 million (USD 2364) per hectare per year. This is the value of non-market ecosystem services that would be derived from agro-ecosystems in India per year.

Table 1 shows the total cultivable land and estimates of potential PES under different scenarios of transition to PAP practices. The total PES was estimated by multiplying the per hectare non-market ecosystem service value by the total cultivable land in the respective regions. This represents the amount to be paid out when farmers adopt a HA, MA and LA option.

The fiscal outlay for agriculture for the year 2017 could be considered for financing the PES. The fiscal outlay was worked out separately for HA and LA scenarios; Figures 1 and 2 respectively present the results.

The total PES payment required to encourage 100% HA option over the entire cultivable land across regions

Table 1. Proposed payment for ecosystem services for non-market ecosystem services under different Scenarios for regions in India

Regions	Total cultivable land (million hectares)	Total PES (INR billion)		
		HA	MA	LA
North	35	1468	1027	514
South	39	1639	1148	574
East	27	1140	798	399
West	57	2385	1669	835
Total	158	6632	4643	2321

HA, High adoption; MA, Medium adoption and LA, Low adoption. Source: Authors' estimates.

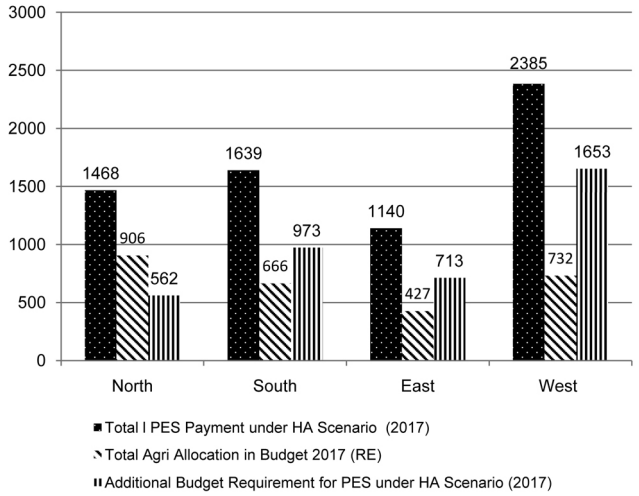

Figure 1. Fiscal requirement for PES under high adoption (HA) Scenario: Regions India (INR billion). Source: Author's estimate.

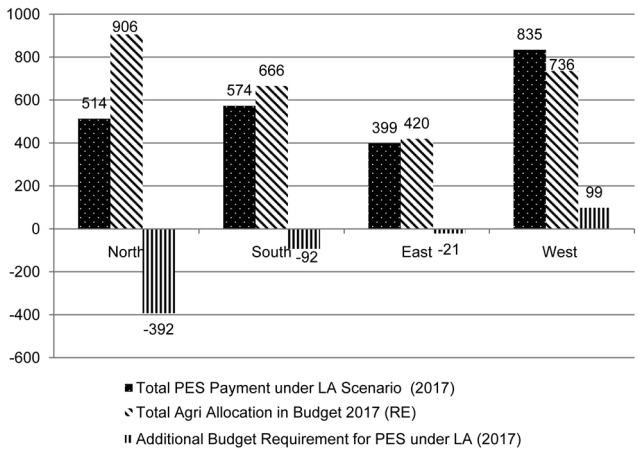

Figure 2. Fiscal requirement of PES under low adoption scenario: regions India (in INR billion). Author's estimate.

ranges from INR 1140 billion (USD 64 billion) in the eastern region to INR 2385 billion (USD 134 billion) in the western region (Figure 1). Under 100% LA option, PES would ranges from INR 399 billion (USD 22 billion) in the eastern region to INR 835 billion (USD 47 billion) in the western region (Figure 2).

Evidently, the LA option is financially feasible even with the current level of budgetary allocation for agriculture in all the four regions except the western region (Figure 2). In fact, the PES mechanism under LA scenario would leave a surplus for the government (from INR 21 billion (USD 1 billion) in the eastern region to INR 392 billion (USD 22 billion) in the northern region). The current budgetary allocation would be inadequate if all the farmers were to adopt HA practices and all regions would require payment. The additional budgetary allocation required is in the range of INR 562 billion (USD 32 billion) in the northern region to INR 1653 billion (USD 93 billion) in the western region (Figure 1).

Discussion

An agrarian economy like India stands to benefit from drawing parallels from the 'incentives and nudges' that are part of a large number of PES/AES schemes implemented in developed economies. India's National Environment Policy had introduced MBIs for managing the environment, which provides a framework for introducing PES in India[24]. Introducing ecological incentives along the lines of PES/AES in agriculture would ensure flow of regulating, supporting and cultural ecosystem services that contribute to overall improvement in ecological health of agro-ecosystems at no income loss to the farmers. The ecological incentives can also be a means for attaining Government of India's target of 'doubling farmer's income by 2022' (ref. 7). The value of non-market ecosystem services estimated from agro-ecosystems per year when provided as an addition to average annual farm income of INR 77,112 (USD 4342)[27] would result in a 50% increase in farm income. Moreover, a PES-type mechanism encourages voluntary adoption of low-input intensive farming practices unlike the conventional price stabilization policy of announcing 'minimum support price' (MSP) for agricultural crops. Moreover, MSP being a cost-based approach does not incentivize farmers to shift to low-input, low-cost farm-

ing. PES-type mechanism is thus an income stabilization mechanism unlike MSP, which is more of a price stabilization policy mechanism. Hence, compensating farmers' equivalent to non-market ecosystem services generated from agricultural activities would significantly reduce their distress through income stabilization and incentivize them to achieve productivity in perpetuity through agriculture that is more environment-friendly, socially beneficial and sustainable.

The existing institutional mechanisms like farmer producer companies (FPCs) could be the vehicles to operationalize PES, with FPCs representing the farmers in marketing ecosystem services. The current budgetary allocation for agricultural development by all individual states and the Union Government could be pooled to meet the financial outlay for implementing PES. The deficit in PES to be paid out under high adoption scenarios; that is, the additional budgetary requirement for implementing PES could be generated from levying a 'cess' for environmental protection reflected in the direct/indirect taxes.

Conclusion

Introduction of a PES-type mechanism for promoting PAP practices would have long-term ecological benefits. However, such a PES scheme would also help double farm income. The current fiscal and institutional environment in the country is conducive to the implementation of PES-type mechanism for transition to PAP practices. Thus, an overall shift from a 'productivity-based approach' to an 'ecosystem-based approach' to agricultural development through implementation of PES mechanism is feasible and would result in productivity in perpetuity along with doubling farmers' income in India.

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