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WORKING PAPER

Transforming the yardstick used to measure benefits from the farm sector: Moving beyond per-hectare yield

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HIGHLIGHTS

- The agriculture sector in India employs almost half of the population in India. Most poor farmers own less than two hectares of land.
- Traditional methods of accounting for productivity ignore the ecosystem services derived from agriculture.
- This paper aims to demonstrate the hidden values of agrisystems, which can be used to improve farmers' income through valuation of agro-ecological elements by using subsidies for hidden costs and incentivizing unaccounted benefits. These unaccounted benefits could be monetized through policy and economic instruments to supplement farmers' income.
- Through a micro-analysis of Barkhedi Abdullah panchayat in Madhya Pradesh, India, the paper uses secondary data to evaluate the ecosystem services or benefits derived from agricultural landscapes.
- A mix of policy and fiscal interventions such as Payment for Ecosystem Services (PES) or Remuneration of Positive Externalities (RPE), tax rebates, and subsidies can promote sustainable agricultural practices.

EXECUTIVE SUMMARY

The agriculture sector provides livelihoods to more than half of the households in India (PIB 2021). The Gross Value Added by agriculture and allied sectors was 18.8 percent in FY 2021–22, and it recorded a growth rate of 3.9 percent in FY 2021–22 (Department of Economic Affairs 2022). The Agriculture Census 2015-16 found, based on the number of operational landholdings, that more than 85 percent of farmers practiced agriculture on less than two hectares of land as owners, tenants, or sharecroppers. The data available raise some concerns that dwindling farmer incomes and employment and the intensifying climate risk will exacerbate poverty among farmers. The Government of India (GoI) set a goal of doubling farmers' income by 2022–23 and appointed an expert committee headed by Dr. Ashok Dalwai. The report authored by the committee recommended empowering farmers, conducting more research and development (R&D) and risk management, and improving agricultural production practices by ensuring that they match the characteristics of the applicable agro-ecological zone (Dalwai 2018).

This working paper augments the findings of the committee's report by adding an important dimension: measurement of the value of natural capital and its associated benefits that can be utilized to address the problem of low income in farming. It uses a framework and approaches developed under The Economics of Ecosystems and Biodiversity (TEEB) initiative to help reveal and quantify the values of biodiversity and ecosystem services and mainstream these into policymaking. Because fallow land can also host important ecosystem services, the land assessed here includes owned agricultural land.

Traditional systems of accounting focus solely on yield-based productivity and ignore environmental costs and benefits. The ecosystem services emanating from the natural capital remain invisible, resulting in overexploitation of natural resources to increase the productivity or yield. However, measuring the value of natural capital can make the agricultural sector more sustainable. This paper attempts to introduce measures beyond yield to provide an important perspective of ecosystem services that if internalized effectively can improve farmers' income and promote sustainable agriculture. Although several studies have evaluated the ecosystem services at the country or regional level, only a few of them have conducted a micro-analysis at the local level. Further, only a handful of studies have investigated the agricultural landscape to measure the ecosystem services it offers.

The paper seeks to address the challenges posed by invisible ecosystem services by integrating economic productivity with environmental productivity. It attempts to measure benefits (ecosystem services) by using a system-based approach covering environmental benefits that aims to make agriculture more sustainable and in the process identify other benefits beyond yield or productivity. It reports the results of a micro-analysis of Barkhedi Abdulla Village panchayat, located near the city of Bhopal, in Madhya Pradesh, India. Given the agrarian structure of the Indian economy, this study is significant because it can serve as one of the inputs for designing policy interventions in the country. The larger objective is to identify ways to raise farm incomes by measuring and compensating farmers for the ecosystem services they provide.

The micro-analysis of the Barkhedi Abdulla panchayat adopted the TEEBAgriFood Evaluation Framework along with WRI's Ecosystem Services Guide for Decision Makers and the Department for International Development's (DFID's) Sustainable Livelihood Framework to account for all the visible and invisible flows of the varied ecosystem services provided by agricultural systems across the entire value chain. The economic valuation of the ecosystem services was done by consulting the secondary literature from various academic sources and published reports. Different elements from the TEEB categories were selected, and values were then assigned to ecosystem elements such as carbon sequestration, pest biocontrol, water retention and conservation, crops, agricultural land, and livestock.

Ecologically sustainable agricultural practices can help provide numerous benefits, which can be internalized to help improve farm incomes. This paper attempts to highlight the value of such agricultural practices. The economic valuation of the area studied showed that adopting ecologically sustainable agricultural practices yielded net benefits estimated at Rs. 473 million annually for a net sown area of 688 hectares (ha). For an average household farm of 1.1 ha, the per capita benefits from adopting agricultural best practices were an estimated Rs. 0.75 million annually compared with the current Rs. 0.12 million annually (NSO 2021). These findings can help formulate policy and fiscal interventions that can improve farmers incomes and livelihoods. These could include economic tools such as Payment for Ecosystem Services (PES) or Remuneration of Positive Externalities (RPE) to reward and transfer money to those who protect or improve ecosystem services. Other interventions could include subsidies and tax rebates to help promote sustainable practices in India's agricultural landscapes.

BACKGROUND, CONTEXT, AND RATIONALE FOR THE RESEARCH

Currently, the agricultural sector accounts for only 17 percent of India's total GDP (World Bank 2022) but engages around 46 percent of the nation's workforce (NSO 2020). The Situation Assessment Survey (SAS) of farm households found that the average annual income of farm households rose by 20.38 percent between 2002–03 and 2012–13.[1] However, between 2012–13 and 2018–19, income growth decelerated to 11.90 percent (NSO 2021). The slowdown was especially striking in income from crop cultivation. The annual growth averaged 21.80 percent between 2002–03 and 2012–13 and dropped to just 4.65 percent between 2012–13 and 2018–19. These trends illustrate the underlying challenges faced by the agriculture sector in India. They fuel concerns over income and employment, the socioeconomic status of farmers, and risks from climate variability and the fragmentation of landholding. Together these factors make agriculture unattractive to young people, endangering the future of the profession in India (Chand 2017).

The GoI's response was a mandate to double farmers' income from 2015–16 levels by 2022–23. An expert Inter-Ministerial committee headed by Dr. Ashok Dalwai was constituted to formulate strategies to increase farmers' incomes. The committee presented its findings in a 14-volume report in 2018, suggesting improving market linkages and enabling self-sustainable models with agro-infrastructure and technological interventions to assist farmers' productivity and income growth. It prioritized improving crop and livestock productivity, using resources more efficiently, diversifying toward high-value crops, and improving marketing (Dalwai 2018).

The report also suggested a shift from farm to non-farm occupations. It especially stressed the need "to develop agricultural production systems in accordance with the agro-ecological situation" (Vol. XIV, p. 20) and address farmers' empowerment, R&D, and risk management (Dalwai 2018). These recommendations hint at detailed analyses of agro-ecological assessment and valuation, in addition to contributions from human and human-made capitals and the value chain impacts of agriculture.

However, in the context of agriculture, traditional productivity accounting systems tend to ignore reporting of environmental consequences. This paper furthers the concept of economic valuation to build up a case for improving farmers' income by measuring the natural capital and associated benefits of agro-ecological systems, which can be monetized or used to identify additional sources of income. The aim of the paper is to demonstrate valuation techniques that can help policymakers design appropriate policy interventions and economic instruments covering the policy-related, market-related, and institutional aspects of incentivizing farmers to generate or improve natural capital and ultimately make agriculture more rewarding and sustainable.

The study attempts to capture the total contribution of the agro-ecological system in the selected area at the panchayat level by using The Economics of Ecosystems and Biodiversity (TEEB) eco-agri-food framework (TEEBAgriFood Evaluation Framework). It aims to assess the stocks, flows, and ecosystem services provided by eco-agri-food systems. Based on the literature review and study framework, a systematic approach is adopted to identify the factors impacting farmers' incomes. Once these factors are identified and measured, it may be possible to better inform farmers about the opportunities and interventions available for increasing farm benefits. This paper focuses on the stocks and flows that are either required for undertaking agriculture or provided by it as a product or outcome along with other qualitative benefits.

To achieve the desired goal, the study adopts The Economics of Ecosystems and Biodiversity for Agriculture and Food (TEEBAgriFood) calculus along with WRI's "Ecosystem Service Guide for Decision Makers" and the DFID's Sustainable Livelihood Framework to account for all the visible and invisible flows of the varied ecosystem services from agriculture across the entire agri-value chain. The objectives of the field study are to identify ways to increase income through cost reduction and enhancement of benefits achieved by internalizing ecosystem services and developing incentive-based mechanisms for ecosystem services.

Augmenting benefits from agri-ecosystem services

In the context of agriculture, traditional productivity-based accounting systems tend to ignore reporting of the environmental consequences. The ecosystem goods and services provided by natural capital remain "invisible" as they are not mainstreamed. That is, they are not incorporated in the economic and financial calculus, which creates a mismatch between market performance and human well-being. The gap results in the overexploitation of natural resources by conventional agriculture to increase productivity and yield, and these activities often directly harm human health and welfare. Bridging this gap requires accounting approaches that integrate economic activity with environmental sustainability.

Agriculture is a sector that is primarily dependent on natural capital. Agricultural producers and people dependent on agriculture are affected by climate variability, water scarcity, soil erosion, and increasing energy prices. Concentrating only on per hectare yields and profits has imposed invisible costs and economic burdens by damaging the environment (Sukhdev et al. 2016).

In view of this lacuna, studies have proposed shifting from the conventional approaches by including natural capital in farm accounting systems (Polmannn 2015). The stock and flow benefits of soil quality, water quality, landscape aesthetics, biodiversity habitats, and so on, can provide a holistic way to integrate environmental factors into the agricultural production function (Dupras et al. 2018; TEEB 2018). The pilot site identified in the study for applying the valuation framework, a panchayat, is from the geographically central state of Madhya Pradesh. Madhya Pradesh was chosen owing to its highly agrarian population: 55 percent of the population is engaged in agriculture compared to the national average of 47 percent. The panchayat, Barkhedi Abdullah, comprises four villages and lies in the Huzur tehsil of the Phanda block in Bhopal district. Led by a woman sarpanch and located in one of the fastest-growing districts on the development scale, Barkhedi Abdullah presents an opportunity to explore means of inclusive and sustainable agricultural growth because of the problems associated with the intensification of conventional agriculture methods. This study evaluates the ecosystem services or benefits obtained from an agricultural landscape through a micro-analysis of Barkhedi Abdulla Village panchayat, near Bhopal in Madhya Pradesh, India. Although several studies have evaluated the value of the ecosystem services provided by forest and wetland ecosystems, only a handful have estimated these values for agricultural ecosystems. Moreover, in contrast to most available studies, which are at the country or regional level, this study attempts a micro-level analysis.

In this research, data from the National Sample Survey (NSS) 77th Round, covering Situation Assessment of Agricultural Households and Land and Livestock Holdings of Households in Rural India, 2019, have been considered for farm income and categorization of farmers. The data taken for reference therefore pertain to agricultural households and not to individual farmers. An agricultural household is defined in the NSS round 77 as "a household receiving more than Rs. 4000/- as value of produce from agricultural activities (e.g., cultivation of field crops, horticultural crops, fodder crops, plantation, animal husbandry, poultry, fishery, piggery, bee-keeping, vermiculture, sericulture, etc.) and having at least one member self-employed in agriculture either in the principal status or in subsidiary status during the last 365 days."

Also, for this research work, agriculture practiced on land owned has been considered rather than on land operated (that is, leased or rented land). As the TEEB framework follows a systems-based approach covering benefits emanating from landscapes, the ecosystem services considered here are those from the entire farmland rather than from cultivable land alone. Fallow land can also provide several ecosystem services; hence, the criterion for selection is land ownership.

THEORETICAL FOUNDATION OF THE WORKING DOCUMENT: THE TEEB ECO-AGRI-FOOD FRAMEWORK

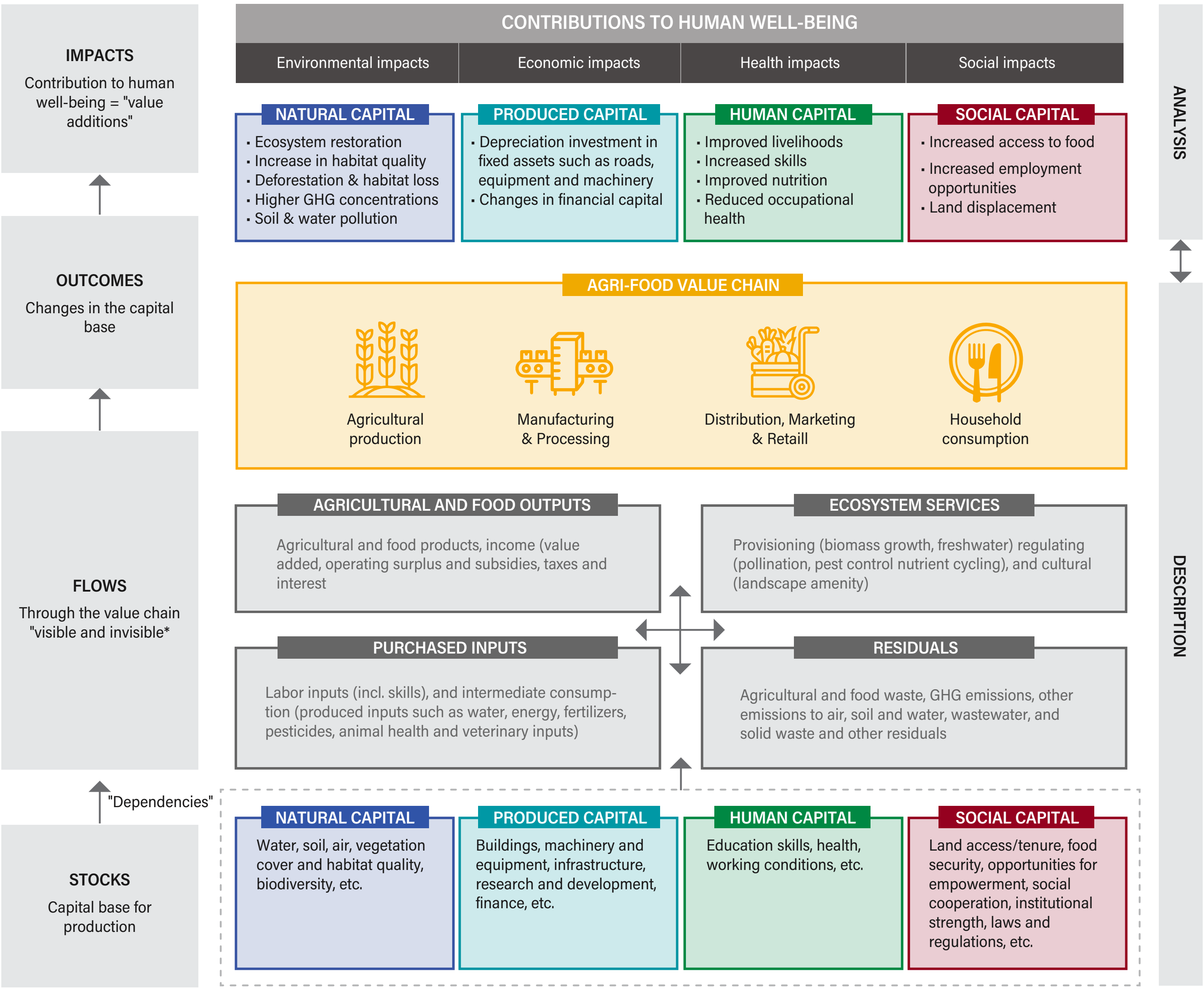
The TEEB eco-agri-food framework used in the study was developed to integrate ecology, agriculture, and human well-being to evaluate agricultural production systems from a holistic perspective. The TEEB framework makes it possible to evaluate agricultural practices from an ecological point of view. The objective is to establish linkages between the food system, the state of human well-being, and the health of people and of our planet, Earth, by going beyond the one-dimensional metric of "per hectare productivity." This requires evaluating the pressures, drivers, dynamics, impacts, and responses in an eco-agri-food value chain. This information can be used to analyze trade-offs and formulate strategies for public policy interventions and promote well-informed changes in farmers' behavior.

The evaluation framework uses four major configurations—stocks, flows, outcomes, and impacts—to evaluate eco-agri-food systems. Four types of assets—natural, produced, human, and social—are considered in the framework (see Figure 1). The stocks represent the capitals, and the values emanating from those are known as flows. An example of a stock is "human capital," which leads to flows of labor and knowledge.

The following examples can better explain the relationship between the different types of capitals. Yield flows, or productivity, contribute to income, which enables investments in produced capital such as machinery and in human capital such as education. Negative flows such as pollution or land clearing will adversely impact natural capital (e.g., by reducing biodiversity or land productivity) and human capital (e.g., by increasing health problems), which in turn may affect labor productivity.

The TEEB framework attempts to capture the interactions between these different forms of capital and the agriculture and food value chain to obtain a holistic picture of the eco-agri-food system. Figure 2 depicts these interactions.

Figure 1 | **The TEEBAgriFood Evaluation Framework**

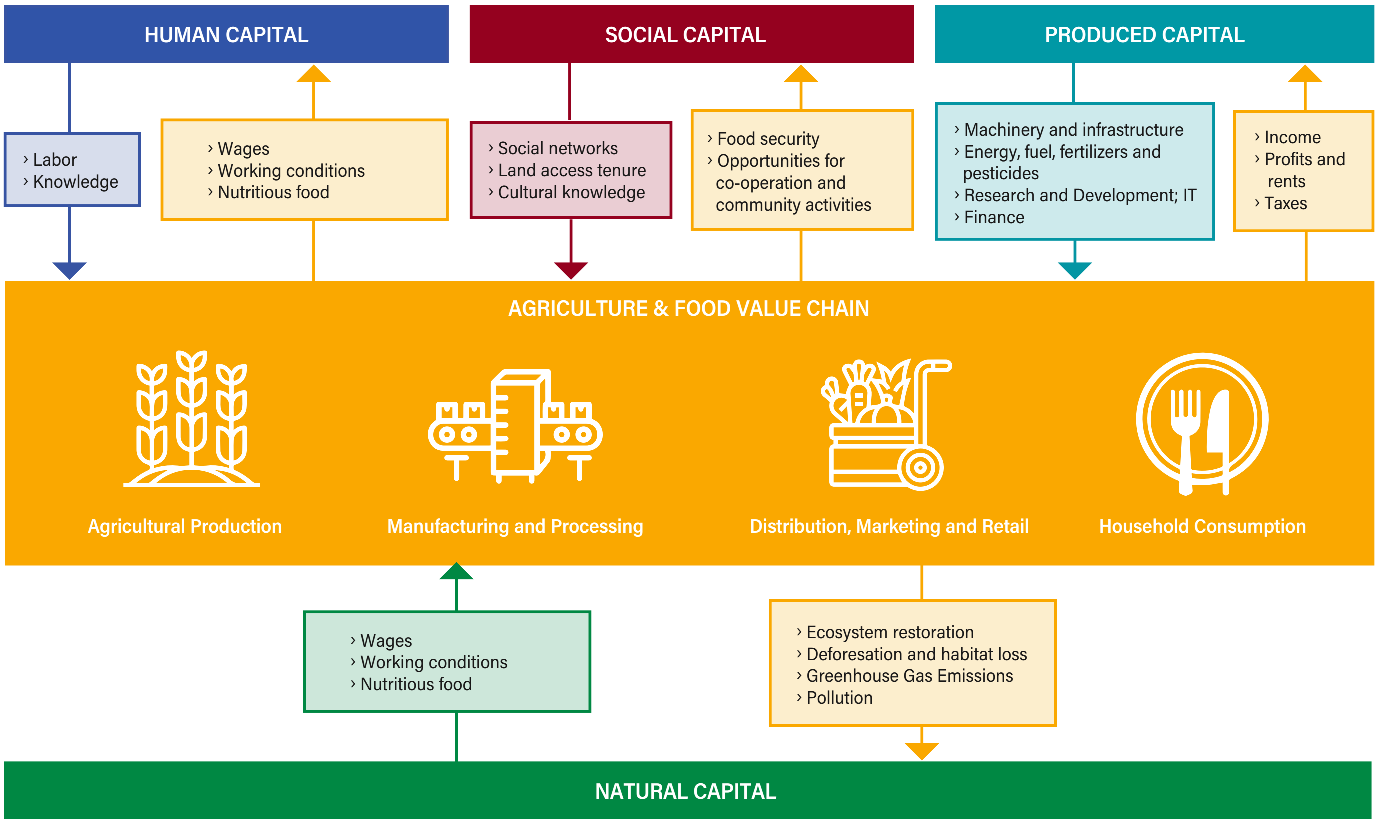


Source: TEEB Agrifood Evaluation Framework 2018.

The remarkable aspect of this framework is its flexibility. It is designed to link various stakeholders—from farmers and processors to consumers and the local communities—along with their interactions and exchanges. Moreover, the framework uses different analytical approaches to compare the trade-offs related to agricultural and food policies, consumption choices, land use, and investment patterns. Several studies have been undertaken in countries such as Colombia, Tanzania, Kenya, Thailand, China, India, and Brazil using the TEEB framework to unravel different aspects of food systems and their relationship with human well-being (IKI Project 2017–2021 by TEEB).

The framework's attributes make it suitable as a tool for evidence-based decision-making. The target audience for the study is primarily policymakers involved in decision-making for agriculture and allied sectors. However, the applicability of such studies is not limited to policymaking and statecraft; other targeted beneficiaries are the corporate sector, agribusiness, and consumers. The study's findings can provide evidence on the co-benefits associated with maintaining sustainable agriculture. Nevertheless, the study's primary objective is to contribute to farmers' well-being by mainstreaming the idea of sustainability in the agriculture domain.

Figure 2 | **Capital stocks and value flows in the agrifood system**



Source: TEEB Agrifood Evaluation Framework 2018.

In brief, this document attempts to analyze three aspects of an agro-ecosystem by understanding the nexus between agriculture and ecology, evaluating agro-ecological services, and making a case for improving farmers' income through policy initiatives.

METHODOLOGY

The basic framework of the study is shown in Figure 3.

Mapping of elements

This entails listing the elements, asset categories, and vulnerabilities involved in bringing together multiple ecosystem services and frameworks such as the Millennium Ecosystem Assessment, Nature's Contribution to People by Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and the Sustainable Livelihood Framework by the Department for International Development (DFID). A detailed analysis was done by consulting published peer-reviewed papers, government reports, and surveys to collate information on the different components of the agricultural value chain. To appropriately reflect the livelihood assets, vulnerability contexts, livelihood strategies, and outcomes, along with the relevant policies, institutions, and cultural aspects, a sustainable framework diagram (see Figure 5) was constructed from a review of the secondary literature. The elements thus identified for the valuation of the agricultural production system and its value chain were listed in different categories in accordance with the TEEBAgri-Food framework.

Study site

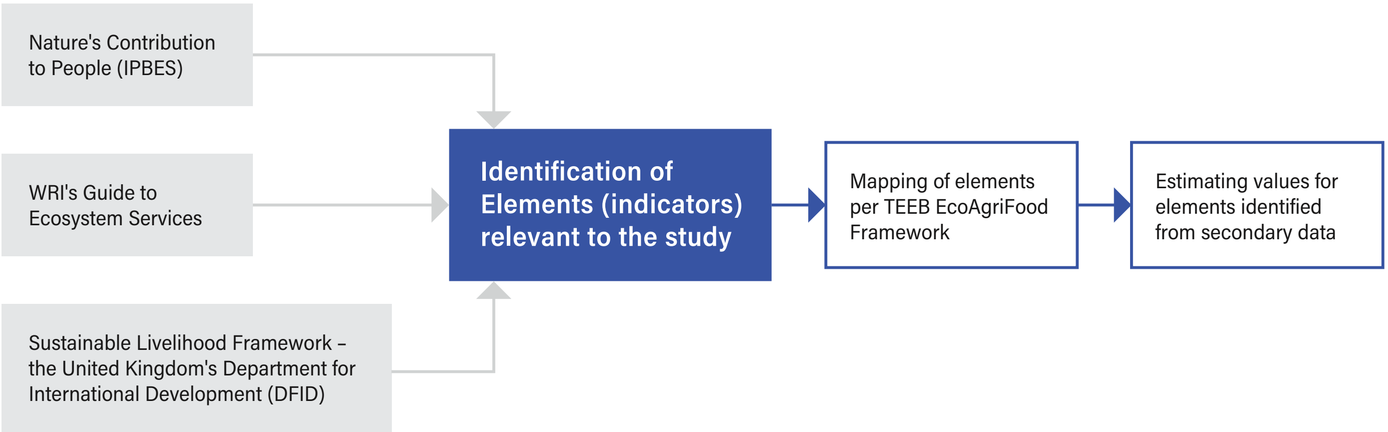
Administration

The Barkhedi Abdullah panchayat lies in the Huzur tehsil of the Phanda community development block in Bhopal district, Madhya Pradesh. According to the Census 2011, it comprises four villages: Barkhedi Abdulla, Dob, Kirat Nagar, and Rusalli Chunanagar.

Geography

The Barkhedi Abdullah Panchayat comprises a total area of 1,839.57 ha. The largest of the villages is Barkhedi Abdulla with 738 ha, followed by Kirat Nagar with 604.28 ha, Dob with 300 ha, and Rusalli Chunanagar with 197.29 ha. The

Figure 3 | **Flow of work: Methodology**



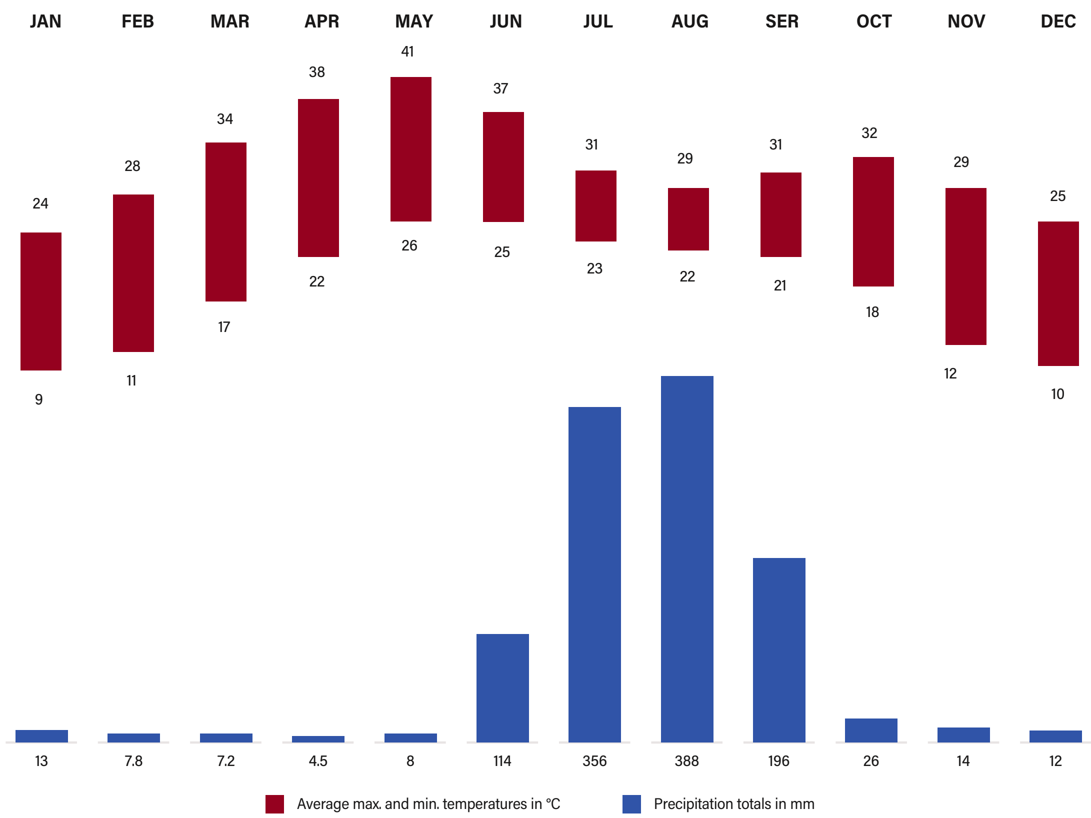
Notes: TEEB = The Economics of Ecosystems and Biodiversity.

Source: WRI authors.

panchayat area falls within the Vindhyan plateau region of the agro-climatic region. The major soil type found in the region is medium black soil (Sharma et al. 2022).

In terms of weather and climate, summers are hot and winters cold, with no extreme weather conditions. There are three clearly distinguishable seasons: summer, rainy, and winter seasons corresponding to March–May, June–September, and November–February, respectively. However, October witnesses a transition from rainy to cold weather, as seen in Figure 4 (Census of India 2011). The Phanda block within which the panchayat lies is drained by the Halai, Kalans, Kaliasot, and Kerwa rivers (Central Ground Water Board 2013).

Figure 4 | **Bhopal climate chart**



Source: Wikipedia 2023.

Valuation of selected elements

Following the approach of "we can only manage what we can measure," we now describe the elements that were identified in the agro-ecological dynamics for assessment under various TEEB EcoAgriFood categories; that is, Capitals (natural, produced, human, and social), Residuals, Ecosystem Services, Agricultural and Food Output, and Purchased Inputs categories in the agro-ecological system. A total of 82 elements were identified for this purpose (see Figure 5). Out of these elements, site-specific data collection and estimation were done for 35 of them. The other elements were left out due to lack of data availability or inapplicability in the context of the field site.

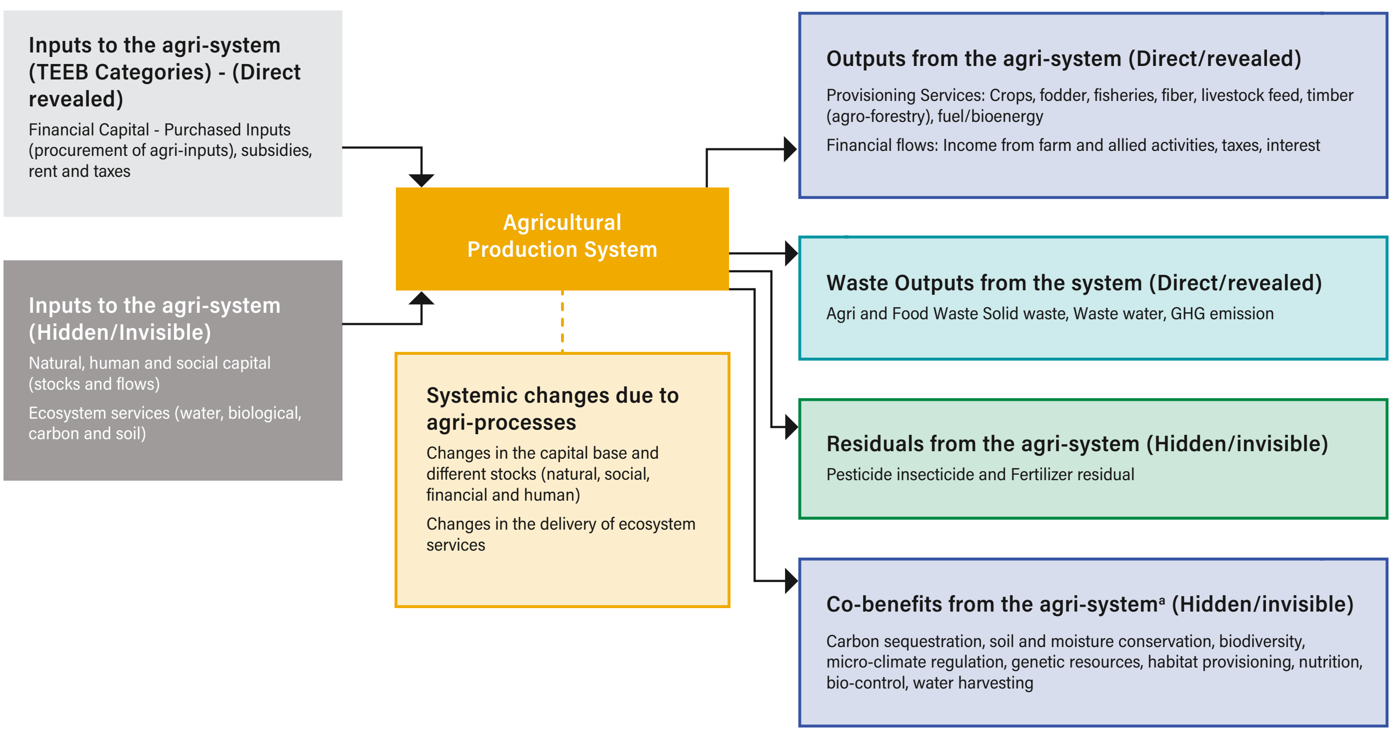
Figure 5 illustrates the interactions between different categories of elements in the agricultural production system. Stocks, ecosystem services, and purchased inputs are provided as input to the agricultural production system, and income and agricultural production are considered its output. This production process causes changes in the capital base (stocks) and delivery of ecosystem services, which can be viewed as an output of the system. The residuals of the agri-output also impact the stocks and flows. This study attempts to depict the relationship between these elements for the study area from an economic perspective.

The valuation estimates are derived by consulting the secondary literature from published papers, government reports, and other organizational reports. The attempt is to develop a case for increasing farmers' income by identifying different elements (e.g., natural capital, ecosystem services) and assigning a monetary value to them. In some cases, multiple scenarios have been developed to model different estimates. All US$ values are converted into Indian rupees at the conversion rate of 1 US$ equals 70 Indian rupees (for each calendar or financial year). The following section describes the estimated values, assumptions, and the methodology used for each element.

Carbon sequestration

Estimating carbon sequestration in agriculture is pivotal for the decarbonization of the sector and India's climate targets. The exercise aims to disincentivize crop residue burning and formulate the monetary benefits associated with sequestering carbon. The above-ground biomass (AGB) and soil organic carbon have been used to estimate the annual carbon sequestration of agriculture. Two scenarios were developed based

Figure 5 | **Interactions between different elements under the broad categories such as Stocks, Ecosystem Services, Purchased Inputs, and Residuals**



Note: a. The extent and impact of the hidden factors vary as per the agri practices (sustainable and non-sustainable.

Source: WRI authors.

on the availability of data in the secondary literature. In both cases, it is assumed that no crop residue is burnt. In the first scenario, the biomass-to-carbon conversion ratio is estimated at 0.47, in accordance with the IPCC standard. The average AGB is estimated at 6.45 tonnes per hectare (t/ha) for wheat (Yue et al. 2017). The annual soil organic carbon sequestration is taken as 0.05–0.5 t/ha (Srinivasarao et. al. 2013). To estimate the economic value of carbon sequestration, four alternative carbon prices were considered: $86, $33, $20, and $10 per tonne (Dynarski et al. 2020; Ninan and Kontoleon 2016). These values stand at $91, $36, $22, and $11 per tonne cost of carbon respectively after adjusting the annual value of the U.S. consumer price index in 2020 for inflation. The total estimated annual values of carbon sequestration by wheat cultivation for the entire panchayat's net sown area were Rs. 49.53–56.7 million (at $91 value), Rs. 19.6–22.4 million (at $36 value), Rs. 11.9–13.7 million (at $22 value), and Rs. 5.97–6.37 million (at $11 value).

In the second scenario, the crop density in the Malwa plateau, Madhya Pradesh, a hot dry subhumid agro-ecological subregion, was considered for estimating the above-ground carbon sequestration (Wani et al. 2010). Soil organic carbon sequestration was calculated for the subhumid Kheri soil type in Jabalpur, Madhya Pradesh (Bhattacharyya et al. 2007). The total estimated values at the 2020 price levels were Rs. 71.11 million (at $91 value), Rs. 28.13 million (at $36 value), Rs. 17.20 million (at $22 value), and Rs. 8.57 million (at $11 value).

Pest biocontrol

The benefit transfer method was used to estimate the value of pest biocontrol. Two scenarios were developed based on the availability of data. In the first scenario, the implied value of an ecosystem service was estimated by using optimal control of soybean aphids in the presence of natural enemies (Zhang and Swinton 2012). The per hectare value for pest biocontrol at the 2020 price level was $6 to $44. The economic value of pest biocontrol for the net sown area was Rs. 2 to 15.7 lakhs annually.

In the second scenario, data on the standardized mean values for pest biocontrol ecosystem services and the biome-cultivated area were obtained from the Ecosystem Services Valuation Database (ESVD) database (de Groot et al. 2020). The values obtained from the database were per hectare per annum values in international dollars at 2020 price levels. Note that the economic estimates are done for representation purposes to highlight the monetary benefits of ecosystem services in the agriculture domain. The values were converted to Indian rupees using the exchange rate from OECD Database for 2019–20 (OECD Exchange Rate Data n.d.). The estimated annual economic value of pest biocontrol in the panchayat was Rs. 29.92 million for the entire net sown area.

Crops

Crops are considered an agricultural system's major output. The total production for the panchayat was estimated using secondary data collected from various sources such as the census and district-level production data. The crop mix selected from census data was wheat, jowar, maize, soybean, and groundnut. In addition, two horticultural crops—potato and onion—were also selected from district-level data (Crop Production Statistics – Bhopal 2019). The district-level production data were used to estimate the land use proportion for the chosen crop mix. The land use proportion was then applied to the net area sown in the study area to arrive at the estimate. The district-level yield was considered to calculate production. The prices of three major crops (i.e., wheat, maize, and soybean) were taken from the Agricultural Produce & Livestock Market Committee (APMC) database of Madhya Pradesh to derive their economic value (APMC-MP Portal n.d.). The prices of other crops were not available and therefore were not included in the economic estimations. Thus, the present study's economic estimates can be considered conservative. The total annual economic value of wheat, maize, and soybean for the entire panchayat is estimated as Rs. 30.44 million for the net sown area.

Agricultural land

The net sown area of the panchayat was used as an estimate of the land area. The average rental value of land for wheat, maize, and soybean was used to estimate the annual economic output of the cultivated land (Ministry of Agriculture 2007). The total annual economic value of the agricultural land of the panchayat was Rs. 1.75 million.

Livestock

The 20th Livestock Census data were used to estimate the number of cattle, buffalos, and goats for the panchayat (Department of Animal Husbandry and Dairying 2019). Milk production was used to estimate the economic value of cattle and buffalos. The value of goats was estimated as its asset value at the market price (Sahoo et al. 2019). The average milk production of a cow was considered 1,600 kg per lactation per year. For buffalos, the average milk production was considered 6.8 kg per day (TNAU Agritech Portal n.d.). The total values of cow and buffalo milk production are Rs. 105.6 and Rs. 50.88 million per annum, respectively. The stock value of goats is Rs. 1.26 million.

Water retention and conservation

Water retention and conservation of the agricultural landscape can also be valued in monetary terms. Several studies have estimated the water retention of forest ecosystems. Ninan and Kontoleon have estimated the water conserved or retained in the Nagarhole national park from rainfall (Ninan and Kontoleon 2016). The study has estimated the economic value of water retention by using the economic cost of storing water in the Kabini dam in Karnataka. Similarly, in this study, we estimated water retention by subtracting the runoff from the annual average rainfall. The economic value of storing water was arrived at by using the benefit transfer approach based on the estimate by Ninan and Kontoleon (2016) to demonstrate an indicative value. Surface runoff was estimated to be approximately 17 percent of the total annual rainfall by taking the average of the values reported by two studies on the Sind river basin (Kumar et al. 2021; Sharma and Kanga 2020). The average yearly rainfall of the Bhopal district was accessed from a monograph published by the Indian Meteorological Department (Guhathakurta and Revadekar 2016). The economic value of water retention from the net sown area at the 2020 price level was estimated as Rs. 0.23 million for conserving 5.75 million cubic meters of water. The major limitation of following this methodology is the lack of information on the runoff rate of the study area.[2] The surface runoff rate in an agricultural landscape will depend heavily on the topography and water conservation structures (e.g., canals, wells, and ponds). Therefore, it is advisable to collect site-specific information such as terrain and slope, soil moisture conservation structures, and soil quality to estimate the value. Ecological modeling can be useful for getting reasonable estimates of these parameters. The economic benefit of water conservation and retention can be improved in an agricultural landscape by constructing rainwater harvesting structures and devising water recycling methods.

Other services

Owing to the lack of site-specific data, ecosystem services such as erosion prevention, maintenance of soil fertility, climate regulation, waste treatment, air quality regulation, regulation of water flows, aesthetic information, opportunities for recreation and tourism, and inspiration for culture art and design are estimated by using the method of benefit transfer from a global meta-analysis study (de Groot et al. 2020). Note that these economic estimates are done for representational purposes to highlight the monetary benefits of ecosystem services in the agriculture domain. The values were converted to the 2020 price level using the OECD Database (OECD Exchange Rate Data). The estimated values for the net sown area in the panchayat for the ecosystem services mentioned at the beginning of this section, in the aforementioned order, are Rs. 8.33, Rs. 1.63, Rs. 0.48, Rs. 1.92, Rs. 0.48, Rs. 0.82, Rs. 19.05, Rs. 149.40 and Rs. 0.77 (all figures in millions), respectively.

In the following section, we attempt to estimate the agricultural costs and purchased inputs for the study area.

Agricultural costs and purchased inputs

Agricultural costs and purchased inputs were measured per hectare area of arable land. State-level data of Madhya Pradesh taken from the cost of cultivation report for principal crops were used (Ministry of Agriculture, 2007). The average of the cost per hectare for the period 1996–97 to 2003–04 was taken for maize, wheat, and soybean to estimate the cost of human and bullock labor, machine labor, seed, fertilizer and manure, rental value of owned land, land revenue, cesses (i.e., special taxes) and taxes, and depreciation on implements and farm buildings. The average annual cost for the net sown area for the aforementioned elements are Rs. 1.55 million, Rs. 0.63 million, Rs. 0.48 million, Rs. 0.54 million, Rs. 0.55 million, Rs. 1.75 million, Rs. 0.003 million, and Rs. 0.18 million, respectively. For irrigation charges, the average annual cost of wheat alone was considered for the same period due to a lack of data. The estimated annual cost is about Rs. 0.74 million. Similarly, for the cost of insecticides, the average annual cost of wheat alone was considered for the same time period, the estimated annual cost for which is Rs. 0.09 million.

FINDINGS

Table 1 summarizes the values calculated for each of the elements, grouped by TEEB categories.

Incentivizing sustainability in agriculture through policy intervention

After analyzing the ecosystem services of the agricultural landscape from an economic perspective, the next step is to encourage farmers to provide these benefits through policy and fiscal measures. Economic tools such as PES or RPE are used to reward and transfer money to those involved in protecting or improving ecosystem services. There have been examples of successful implementation of PES in agriculture. In the Uluguru mountains of eastern Tanzania, farmers located upstream received payments from downstream organizations (industrial water suppliers, Coca-Cola, etc.) for adopting sustainable practices (agroforestry, intercropping, animal fertilizer using manure) to limit runoff, combat soil erosion, and increase soil moisture and productivity (FAO 2011a). Countries such as Costa Rica, Mexico, and China have initiated large-scale programs that provide direct benefits to landowners for adopting land use practices aimed at increasing hydrological services, biodiversity conservation, erosion prevention, carbon sequestration, and scenic beauty (Jack et. al. 2008). The findings of this study suggest that similar policy interventions through economic instruments such as PES or RPE, subsidies, and tax rebates can help promote sustainable practices in India's agricultural landscapes.

Table 1 | **Annual economic value of major ecosystem services and costs for Barkhedi Abdullah panchayat, Madhya Pradesh, India**

ECOSYSTEM SERVICES				
Carbon sequestration	Wheat cultivation at cost of carbon	Rs. 49.53 - 56.7 (at \$91 / tCO_2) Rs. 19.6 - 22.4 (at \$36 / tCO_2) Rs. 11.9 - 13.7 (at \$22 / tCO_2) Rs. 5.97 - 6.37 (at \$11 / tCO_2)	Million	INR
Agroforestry/mixed cultivation and water conservation	Per hectare arable land	0.82	Million	INR
Regulation of air quality	Per hectare arable land	0.48	Million	INR
Recycling of waste water/SWM practices	Per hectare arable land	1.92	Million	INR
Regulation of microclimate	Per hectare arable land	0.48	Million	INR
Soil fertility maintenance	Per hectare arable land	19.05	Million	INR
Recreation and tourism (orchards/ pastures/plantations/agroforestry)	Net sown area	149.4	Million	INR
Cultural ecosystem services	Net sown area	0.77	Million	INR
Economic value of pest biocontrol	Per hectare arable land	29.92	Million	INR
Erosion prevention	Per hectare arable land	8.33	Million	INR
AGRICULTURE OUTPUT				
Economic output (wheat, maize, soybean) of cultivated land	Per hectare arable land	1.75	Million	INR
Milk production from cows and bufalows		156.4	Million	INR
Stock value of goats		1.26	Million	INR
INPUT COST				
Cost of seed	Per hectare arable land	0.54	Million	INR
Human labor	Per hectare arable land	1.55	Million	INR
Bullock labor	Per hectare arable land	0.63	Million	INR
Fertilizer and manure	Per hectare arable land	0.55	Million	INR
Irrigation charges	Per hectare arable land	0.74	Million	INR
Insecticides cost	Per hectare arable land	0.09	Million	INR
Depreciation-land and implements	Per hectare arable land	0.18	Million	INR
Cost of land revenue, cess and taxes	Per hectare arable land	3799	Million	INR
Rental value of owned land	Per hectare arable land	1.75	Million	INR

Source: WRI authors.

DISCUSSION

This study measures the contributions of agri-ecosystems for policy purposes. Its goal is to ultimately build a foundation both for designing policy tools for fiscal transfer to incentivize the farmers engaged in sustainable practices and for upscaling the already existing agro-ecological interventions. Tables 2 and 3 summarize the findings.

The flow benefits of agriculture and allied sectors for a net sown area of 688 ha for the selected elements can be as high as approximately Rs. 473 million annually. Therefore, the approximate per hectare economic benefit can be Rs. 0.68 million annually in the study area if agro-ecological best practices are followed. In terms of per capita value benefits for the entire population of Barkhedi Abdullah panchayat, the estimate is approximately Rs. 0.17 million annually. Considering an average household farm holding size of 1.1 ha, the annual potential value benefits per household was estimated as Rs. 0.75 million. However, according to the 2019 NSS report (PIB 2021), the average annual farm income of a farmer household in India is Rs. 0.12 million. The average annual cost of cultivation for the entire net sown area in the village panchayat is approximately Rs. 6.54 million. Considering the cost, the net annual benefit of agriculture, including the associated flow benefits, in the selected village panchayat is estimated as Rs. 466 million.

Table 2 | **Summary of findings**

TEEB CATEGORY	ELEMENTS	VALUE (IN MILLION RS.)
Produce or Crops	Wheat, maize, and soybean	30.44
Agricultural Land	Rental value of land	1.75
Livestock	Cow	105.6
	Bufalow	50.88
	Goat	1.26
Agricultural cost	Human and bullock labor	1.55
	Machine labor	0.63
	Seed	0.48
	Fertilizer and manure	0.54
	Rental value on owned land	0.55
	Land revenue	1.75
	Cesses and taxes	0.003
	Depreciation on implements and farm buildings	0.18

Source: WRI authors.

Table 3 | **Ecosystem services estimation (summary)**

ECOSYSTEM SERVICES	VALUE (IN MILLION RS.)
Carbon sequestration	49.53–56.7 (at $91/tCO2)
	19.6–22.4 (at $36/tCO2)
	11.9–13.7 (at $22/tCO2)
	5.97–6.37 (at $11/tCO2)
Pest biocontrol	29.92
Water retention	0.23 (for 5.75 million cubic meters of water)

Source: WRI authors.

LIMITATIONS

This study mainly focuses on the various visible and invisible benefits of agriculture, using assumptions to provide a pathway to sustainability in the sector. Due to lack of data, the disservices of agriculture were not estimated for this study; hence, the values provided here are gross conservative estimates.[3] These values are also specific to the practices followed and will change depending on the agriculture method used on the ground. Further research should be conducted to estimate the net values of the services and their linkages with different agricultural practices. Another limitation of the study is the lack of field-level data on the economic estimates of some selected elements; these restrictions were compounded by the COVID-19 pandemic. However, this study undertook a novel approach to highlight the benefits, including co-benefits, derived from agriculture from the perspective of ecological economics.

This study adopted a system-based approach to realize the hidden values in the agrifood system, which were demonstrated through selected examples to indicate how the approach can be incorporated in policy. However, suggesting policy pathways will require studying existing institutional mechanisms and current policy features, which was not a part of this study. Also, the analysis was limited to identifying elements of agrifood systems and conducting a valuation exercise for the selected elements. However, the impact of those elements has not been studied.

The quality of the ecosystem services may vary depending on the region's climatic patterns, demographics, land ownership, agriculture practices, and perceptions across and within agro-ecological regions. Such complexities have not been accounted for in this work.

This work attempts to demonstrate the usefulness of the TEEB approach. To arrive at larger conclusions to inform policy, the framework needs to be tested across various regions, particularly agro-ecological zones for various agriculture crops.

The study's findings indicate that ecologically sustainable agriculture has the potential to significantly increase farmers' income and well-being. This opens new pathways to explore aspects of sustainable agriculture with the suggested TEEB framework and identify ways to improving farmers' income through innovative policy and fiscal interventions.

APPENDIX A: FRAMEWORKS USED IN THE STUDY

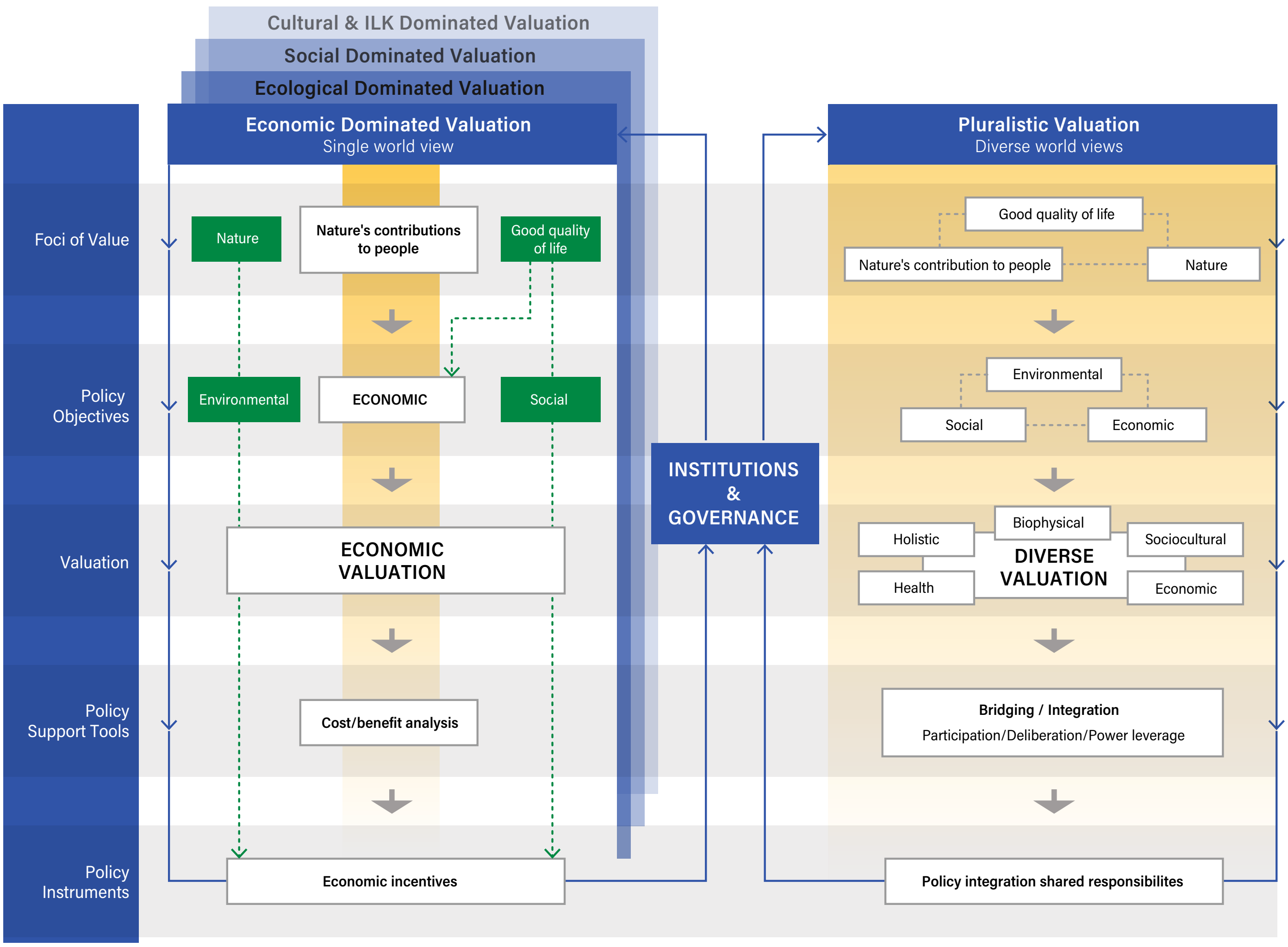
The frameworks used in this study are briefly explained in the following sections.

Nature's Contribution to People: The IPBES approach

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) discusses the valuation of Nature's Contribution to People (NCP) in decision-making. The approach is especially applicable as a knowledge–policy interface to acknowledge the diversity of values and the relationship between environmental, social, and economic factors.

As depicted in Figure A-1, the NCP approach combines diverse worldviews from multiple stakeholders in the valuation metric. This can be understood from an agricultural perspective with an example. Farmers can value the food they produce differently. The produce can be looked at from a purely financial perspective, that is, as a market commodity; it can also be considered an expression of cultural identity. Therefore, the framework focuses on the interplay between different worldviews and their associated values (Pascual et al. 2017).

Figure A-1 | **Comparing the NCP approach with the traditional approach**



Note: ILK = indigenous and local knowledge.
Source: Pascual et al. 2017.

WRI's Guide to Ecosystem Services

World Resources Institute's Guide to Ecosystem Services explores the links between ecosystem services and human well-being by relying on the Millennium Ecosystem Assessment framework. Its purpose is to improve decision-makers' understanding of ecosystem services and to estimate their value.

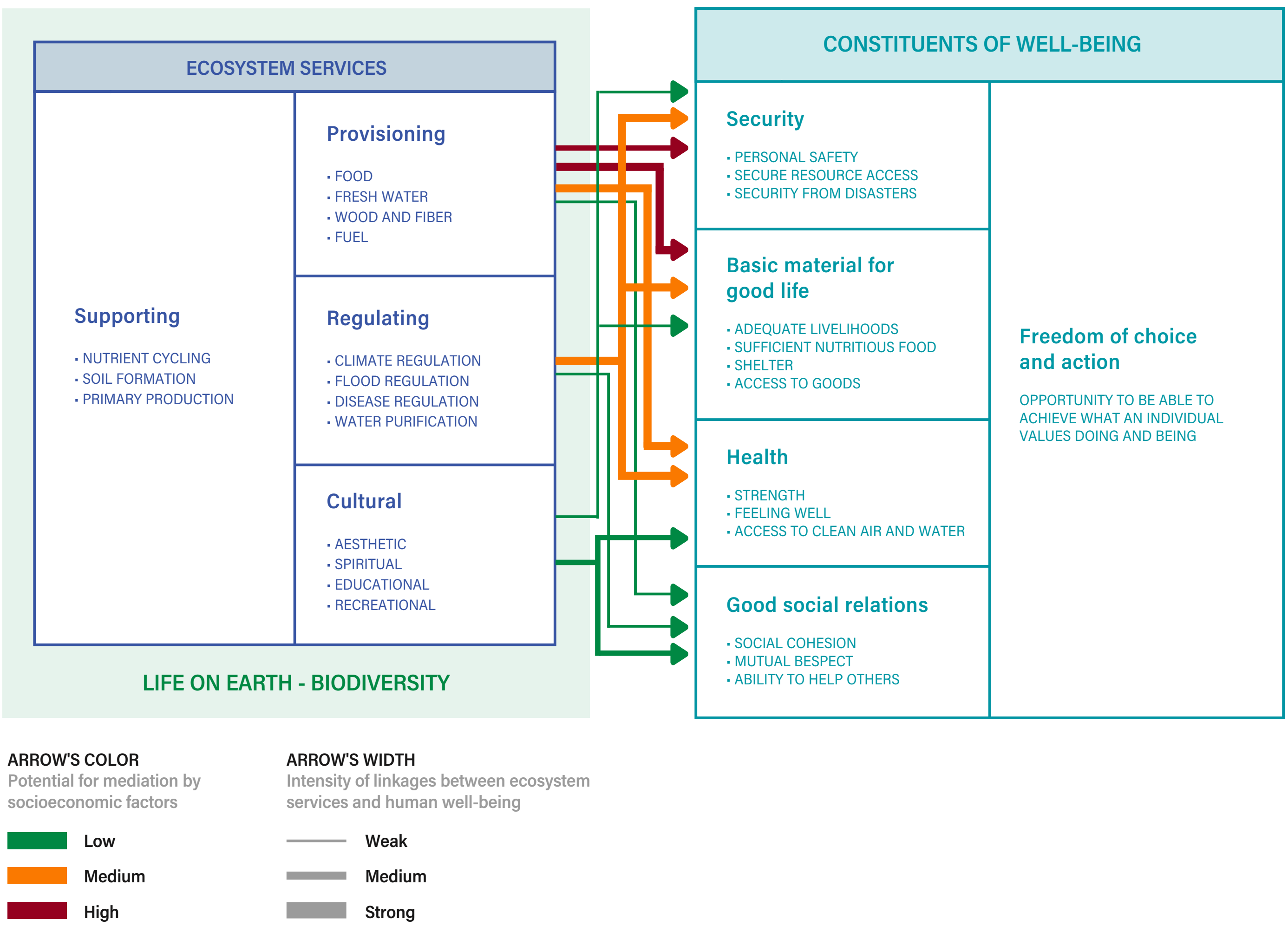
As shown in Figure A-2, the arrows represent the strength of the links between ecosystem services and human well-being. The concept is helpful for policymakers because it highlights focus areas for policymaking or interventions (Ranganathan et al. 2008).

Sustainable Livelihood Framework: The United Kingdom's Department for International Development (DFID)

To conceptualize the livelihood aspects of agriculture in a holistic way, the DFID framework is considered here. This analytical framework considers five forms of capital (human, social, natural, physical, and financial) in assessing sustainable livelihood projects (DFID 1999). Figure A-3 illustrates the capitals and vulnerability contexts to depict the interactions between elements and different components of the value chain. The livelihood outcomes and possible strategies discovered by conducting a focused literature review are also listed.

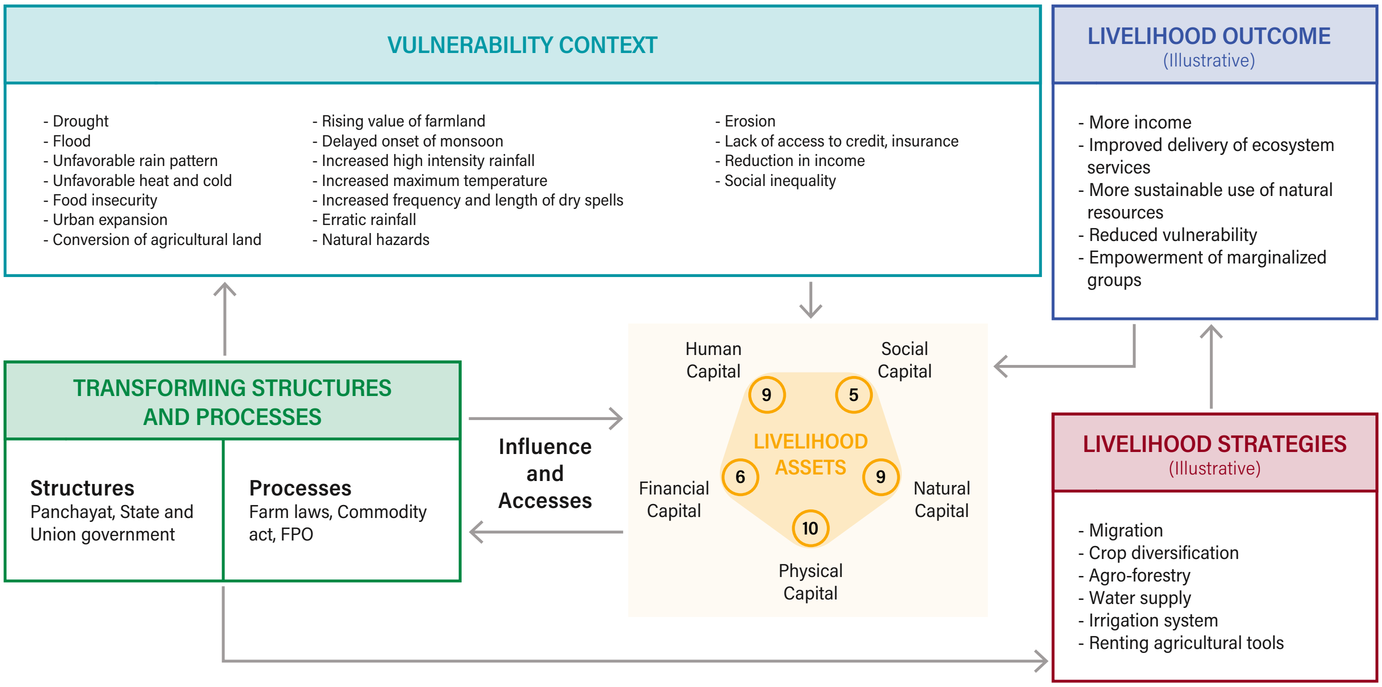
This study emphasizes agro-ecological interventions covering irrigation practices, crop diversification, and agroforestry for improving farmers' income through fiscal measures.

Figure A-2 | **The links between ecosystem services and human well-being**



Source: Reid et al. 2005.

Figure A-3 | **DFID framework visualized based on literature review**



Notes: DFID = Department for International Development; FPO = farmer producer organization.

The number of elements used to map each asset category is indicated within the circles of the Asset pentagon.

Source: Pascual et al. 2017.

APPENDIX B

The elements of the TEEB framework

This section will describe the various attributes of TEEBAgriFood, an eco-agri-food framework based on the TEEB methodology (TEEB 2018). According to this framework, the elements of the eco-agri-food system encompass stocks, flows, outcomes, and impacts (as shown in Figure 1). These elements and their interactions give a holistic picture of the sustainability aspects of the overall agricultural value chain.

The TEEB eco-agri-food framework classifies the stocks or assets into four types of capital: natural, produced, social, and human. The ecosystem goods and services are flows that interact with other elements of the framework and different components of the agricultural value chain. In this section, we will briefly describe these elements to illustrate their significance in the study context.

Ecosystem services

Ecosystem service flows originate from ecosystem functions, which refer to an ecosystem's habitat, system properties, and processes. The goods (e.g., food and fodder) and services (e.g., waste assimilation) derived from the ecosystem functions of agronomy are known as ecosystem services (Costanza et al. 1997). The relevance of these ecosystem services varies depending on the production system and its output (TEEB 2018). For example, ecosystem services such as soil conservation and water retention serve as inputs to agricultural production by helping farmers grow different types of crops. Apart from the ecosystem services, the ecosystem disservices (e.g., GHG emission) emanating from the agrifood system are also relevant in the context of this study.

- **Soil conservation/sediment regulation -** Soil conservation or retention primarily depends on the structural aspects of the ecosystem, such as vegetation cover and root systems (de Groot et al. 2002). The root systems stabilize soil, and the foliage intercepts rainfall to prevent soil erosion and facilitate sedimentation. Soil conservation is an agricultural input augmentation, enabling current and future increments in agricultural outputs. Therefore, the economic value of this contribution to agriculture can be estimated by using the concept of "avoided cost" due to sedimentation (Verma et al. 2017). This approach considers the soil's erosion-preventing effect as a flow of natural capital (Barry et al. 2011). In this regard, the unit chosen could be annual tonnes per hectare (Pimentel et al. 1995).
- **Nutrient recycling -** Forests and vegetation cover prevent soil erosion into rivers and streams, limiting nutrient loss (Verma et al. 2017). Soil nutrients are essential for sustaining agriculture and can be measured by estimating the soil's nitrogen,

phosphorus, and potassium (NPK) composition. The economic value of nutrient recycling can be estimated by using the replacement cost of fertilizers (Ninan and Inoue 2013).

- **Carbon sequestration** - Carbon sequestration refers to the process of removing atmospheric carbon dioxide and adding to the existing carbon stock. Plants facilitate the sequestration of carbon through photosynthesis and store it as an organic compound. Farming areas and grazing lands provide this ecosystem service. Carbon sequestration by agricultural soil and plants can be measured in peta-gm (for soil organic carbon) and in tonnes per hectare (for plants) (Nayak et al. 2019; Nowak et al. 2013). The economic value of the sequestered carbon can be measured by using the market price or carbon price, and the social cost of carbon can be measured by using carbon trading markets.
- **Biological pest control** - Biological control refers to controlling pests (e.g., insects, mites, weeds) by using other organisms. The significant advantage of using such methods compared to chemical fertilizers is that they do not cause pollution or release harmful residuals in soil and water bodies. Therefore, the economic valuation of biological pest control as an ecosystem service is an area of interest in this study. In the context of agriculture, the species richness of the natural enemy of agricultural pests can be considered an indicator to estimate the level of biological pest control for farming areas (Letourneau et al. 2015). The economic valuation can be done by calculating the relative change in yield achieved by using biological pest control compared with that achieved by using chemical pesticides.
- **Pollination** - Pollination is the process of transferring pollen from the male anther of a flower to the female stigma. This leads to fertilization and the production of seeds. Pollinators such as bees and birds carry out the vital function of pollination. For agricultural production systems, pollination is an essential service provided by nature.
  The pollinator population and its supply of pollination services are associated with higher agricultural productivity and therefore is an economic output (Hanley et al. 2015). Sustainable agriculture can support the pollinator population and may increase yield productivity in nearby areas.
- **Spiritual and religious inspiration/learning and inspiration -** Historically, agriculture has been a source of spiritual and religious inspiration for the farming community. The inspiration comes from a sense of protectiveness toward the gods and Earth (Ikerd 2019). Although the advent of industrialized agriculture has led to a shift in this regard, in India's context of eco-agri-food systems, it is essential to highlight the economic aspect underlying this concept. The number of people involved in spiritual and religious movements can be used as a proxy to estimate the impact of this specific element. A monetary estimate can be derived through surveys by capturing changes in yield through the abovementioned movements.

Apart from the abovementioned ecosystem services, agricultural systems provide other benefits such as climate regulation, cultural services, waste treatment, identity support, physical and psychological experiences, and so on.

Flows of natural capital: Agricultural inputs and outputs

Natural capital can be defined as the finite stock of physical and biological resources found on Earth, along with the capacity of the ecosystems to provide ecosystem services (TEEB 2010). Natural capital may include all mineral and energy resources, biological resources, land and soil resources, and all ecosystem types (e.g., agricultural areas, forests, wetlands, marine) (TEEB 2018).

In the context of agricultural production systems, natural resources such as water, soil, nutrients, atmospheric CO_2, land quality, sunlight, ecosystems, and biodiversity can be considered flow inputs. On the other hand, agriculture produces outputs such as crop by-products, crop and fertilizer residue, CO_2 and other greenhouse gases, and changes in land use and in the quantity and quality of water resources. We will focus on the stocks and flows that are either required for undertaking agriculture or emanate from it as a product or outcome.

- **Water supply and quality -** Vegetation and soil biota filter water. The natural filtration process is vital for maintaining water quality, which is one of the most critical inputs to the agricultural production system. The water supply function depends on the ecosystem services and their role in the hydrological cycle (de Groot et al. 2002).
  Agricultural pesticide and fertilizer residues impact water quality. They influence the concentration of phosphorus, ammonia, and nitrate compounds (mg/L), biological oxygen demand, organic carbon, and temperature, and these can be considered measures of water quality (Lowicki et al. 2012).
- **Air quality** - Air quality regulation is another ecosystem service provided by vegetation cover. Studies have shown that urban forests mitigate air pollution in cities (Baró et al. 2014). Depending on the practices followed, agriculture can either help or harm air quality; that is, it may be a service or a disservice. Capturing the environmental pressures on air quality from agriculture and food processing systems thus becomes important (International Resource Panel United Nations Environment Programme 2010). For example, it is possible to estimate the economic gains due to improved human health when fine particulate (PM 2.5) pollution from agricultural emissions is reduced (Giannadaki et al. 2018).

- **Habitat quality -** Habitat refers to the combination of resources, biota, and other factors present in an area where organisms live, reproduce, and find shelter. A healthy habitat is necessary to provide several ecosystem goods and services. For this reason, habitat quality in areas adjacent to farmlands is vital for the agricultural food production system. Habitat quality can be estimated in terms of the wildlife population supported and the nursery function provided by the area under consideration (de Groot et al. 2002; Verma et al. 2017).
- **Biodiversity** - The Convention on Biological Diversity (CBD) defines "biological diversity" as the "variability among living organisms from all sources such as, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; including diversity within species, between species and of ecosystems" (Article 2, CBD). Biodiversity provides critical ecosystem services as an agricultural system input (TEEB 2018). An example of this is vegetation providing a habitat for pollinators, which assist farming in nearby areas by engaging in seed dispersal and pollination. Biodiversity can be measured by the species richness of a particular location. The contribution of biodiversity to agricultural production can be estimated using an economic lens by associating changes in crop yield with increased or decreased biodiversity.
- **Medicinal resources** - Nature provides various chemicals that can be used as medicines or to manufacture drugs. Animals are also applied as medical tools; for example, medicinal leeches are applied to reduce blood pressure (de Groot et al. 2002). This particular natural capital has great implications for preserving human health and may be considered an output of the agricultural production system.
- **Biological nitrogen fixation** - Biological nitrogen fixation is carried out by a particular type of microorganism (prokaryotes) that converts atmospheric nitrogen into ammonia. The plants then assimilate ammonia and produce nitrogenous biomolecules (Wagner 2011). This is a vital input to the agricultural system because the health and growth of plants depend on the assimilation of ammonia.

Flows from produced capital

Produced capital includes manufactured capital such as machines, infrastructure, buildings, equipment, roads, water systems, intellectual capital (e.g., patents, brands, and software), and financial capital (TEEB 2018). The World Bank considers produced capital an asset category in wealth accounts, for instance, by measuring the market price of infrastructure such as machinery, buildings, and equipment (Lange et al. 2018).

The agrifood value chain includes produced capital owned by individuals, built infrastructure that supports the agrifood value chain (road and rail networks, dams and irrigation systems, ports, and airports). It also includes knowledge generated through research and innovation.

On the other hand, social or human capital refers to the knowledge of the people and communities involved in farming and related activities. For informed policymaking, it is necessary to understand and observe the most direct linkages between produced capital and other asset categories (e.g., natural, human, and social). The links provide insight into the intersection of economic activity, environmental stewardship, and social and human well-being

- **Financing** - Financial capital is a necessary input for agrifood systems. The financial input may come from credit, public and private investment, or any combination of these. In the context of agriculture, financial capital pertains to investment made in rupees or the debt-to-asset ratio of the household (Ifft et al. 2013).
- **Machines** - Several types of machines are used as input to agrifood systems. The mechanization of agriculture has led to considerable dependence on equipment and machinery. Economic valuation of the machinery and infrastructure can be calculated using their market price or replacement cost.
- **Infrastructure** - Agricultural infrastructure such as transport, workforce, technology, and processing units are required for the agrifood system to produce its outputs. The economic valuation of infrastructure may be done using its cost of rent or purchase.
- **Research and development** - Another important produced capital from agriculture is research and development. Many studies in this discipline provide research findings that are vital to human well-being and the sector's overall development. The research output can be estimated in terms of patents, research papers, reports, and doctoral theses for the specific domain of interest, which in this case is agriculture.
- **Bioenergy** - The energy generated from biomass or biofuel can be referred to as bioenergy. Biomass is used as a raw material in processing bioenergy. Examples of biomass are wood and crop residue. Fuel can be in the form of pellets and briquettes, or it can be used directly. Bioenergy is an output of agriculture and can be estimated by using the market price. Bioenergy can be measured by using the production rate or yield of biomass (t/ha) (Rocha-Meneses et al. 2020).

Flows from social capital

Social capital covers the shared norms, values, and understandings that facilitate cooperation within or among groups (Healy and Cote 2001). This form of capital includes common rules, relations of trust, norms and sanctions, reciprocity, and connectedness in institutions (Pretty and Ward 2001). Determining the boundary for measuring social capital in the eco-agri-food framework is complicated. The focus should be on social capital's contribution to the eco-agri-food chain (TEEB 2018).

Although measuring social capital is a complex task, some elements such as participation in local organizations, social inclusion, adherence to norms, and collective actions can be used to arrive at relevant yardsticks (Grootaert et al. 2002). Social equity is another important concept that should be highlighted to gauge social capital.

- **Indigenous agricultural innovations -** Indigenous agricultural knowledge may be defined as the application of people's skills, experiences, and insights to maintain or improve their livelihood (Okello-Obura 2018). This knowledge may include the use of local varieties of crops, deployment of irrigation mechanisms based on traditional knowledge, and traditional wisdom in managing resources. The knowledge system can be analyzed for its contribution to food production and its role in producing cultural knowledge and supporting identity (Bebbington 1991). Indigenous knowledge can be captured by conducting surveys, and also through the scorecard method and attitude scale (Malhotra et al. 2003; Meenakshi et al. 2015).
- **Land access -** Access to agricultural land is an essential aspect of social capital. Land is often recognized as a primary source of wealth, social status, and power. Access to land ensures shelter, food, and economic activities such as agriculture (FAO 2011b). The quality and quantity of land holding often become the determining factor in social inclusion or exclusion. Thus, for agricultural systems, it is vital to capture various aspects of land access in monetary terms. The indicator of access to land can be found in Sustainable Development Goal 5.a.1 (by gender). This indicator measures land access by using the proportion of the total adult population with ownership or secured tenure land rights (Commission on Genetic Resources for Food and Agriculture n.d.).
- **Food security** - The term *food security* was first defined at the World Food Congress in 1974, emphasizing the supply side of food. Later, the Food and Agriculture Organization (FAO) talked about the balance between the supply and demand sides of the food security equation: "Ensuring that all people at all times have both physical and economic access to the basic food that they need (FAO 1983)." In recent times, food security's ethical and human rights angles have also come into focus (FAO 2006). Given the evolution of the definition of food security in the last few decades, it is important to determine the concept's boundary while attempting to capture the economic value of the social capital under discussion. Food security and social capital are deeply interlinked and exchange synergies by strengthening each other. Advancement or development in social capital affects the food security in the area, and vice versa. Multiple indicators can be used to estimate food security, such as calories per capita, the amount of money spent on food and other necessities, an individual's dietary intake, anthropometry indicators (such as height and weight), and an experience-based scale. The choice of indicator may vary from case to case (Pérez-Escamilla and Segall-Corrêa et al. 2008; Searchinger et al. 2019).
- **Opportunities for employment -** Agriculture generates employment opportunities, especially in rural areas. According to the World Bank (International Labour Organization estimate), approximately 26.49 percent of the total employment in the world came from agriculture in 2020. In India, the contribution of agriculture to employment generation was 41 percent of the total employment in 2020 (World Bank n.d.). The immense social capital generated by the agriculture sector comes within the purview of this and similar studies.
- **Social cooperation -** Social cooperation is a driving factor in the domain of agriculture. A study from Turkey indicates that membership in an agricultural development cooperative is a significant factor in improving livelihoods in terms of income and eating habits. Such membership augments social capital by building trust among members (Kustepeli et al. 2020). Therefore, it is vital to consider the impact of social cooperation on the agricultural production system. Community surveys are conducted to collect relevant information on social cooperation.
- **Institutions** - Institutions and organizations in the domain of agriculture increase social capital by inducing cooperation. Farmers' cooperatives are an example of institutions operating in the agricultural value chain. The role of institutions and social capital in agricultural success has been observed in Central and Eastern European countries (Slangen et al. 2004). Here, the impact of social institutions on productivity and human well-being is assessed from an economic viewpoint.
- **Laws and regulations** - Laws and regulations govern the functioning of society and are important to maintain order and facilitate structured growth. Under the study framework, social laws are covered; these laws help enhance and conserve our social capital.[4] Examples of such laws are labor laws, occupational health and safety regulations, and laws protecting vulnerable groups. The ecosystem service generation from laws and regulations such as this can therefore be valued in monetary terms for informed policymaking.
- **Women's empowerment** - Women's empowerment in agriculture is an important aspect of social capital. The participation and empowerment of women are often associated with other factors such as food security, child nutrition, and poverty. Women's empowerment in agriculture is closely linked with social conditions and gender equity, as they constitute part of the agri-work force, are involved in agro-processes, and are a central pillar of agri-households.
  Women's empowerment can be measured by estimating the influence and inclusion of women in agriculture by using the Women's Empowerment in Agricultural Index (WEAI).[5] The index uses two sub-indices containing several domains such as decisions about agricultural production, control of expenditure,

leadership in the community, relative empowerment gap with men in the household, and so on, to estimate women's empowerment in agriculture (Alkire et al. 2013).

Flows from human capital

Human capital is an asset or resource consisting of the skills of the labor force. From that perspective, investment in people in terms of education, health, training, and other areas improves the asset's quality and thus its productivity (Goldin 2019). It also denotes the knowledge, skills, and attributes of individuals that aid in personal, social, and economic well-being (Healy and Cote 2001).

Under this overarching background, we will explore human capital in the context of agriculture. The human capital of the labor force of the farming community is measured. Factors such as the age, migration status, gender composition, and other dimensions of the workforce can be considered in the measurement. The employment and skill aspects of human capital are direct inputs to the agricultural production system, and different conditions of employment generation are related to social outcomes that can impact the eco-agri-food value chain.

- **Working conditions** - Poor wages and health hazards often impact working conditions in the agriculture value chain. Specific indicators devised by the International Labour Organization (ILO) can be used to evaluate the working conditions in agriculture (Oya 2015). These indicators use multiple dimensions to assess working conditions effectively.
- **Human health** - Health is one of the most critical stocks considered within the human capital category. In the context of agriculture, the use of chemical fertilizers and pesticides adversely affects the health of agricultural workers, whereas natural or organic farming can reduce the harmful impacts on health and health-related expenses of workers and consumers. In estimating the economic value of human health, the statistical value of life (taking mortality) or medical expenditure can be considered effective indicators (Becker 2007).
- **Food nutritional diversity** - There is a strong association between the nutritional variety of national food supplies and key health outcomes (Remans et al. 2014). Agricultural systems providing various food products contribute to the dietary balance of consumers and improve health conditions. A diversity matrix can help estimate nutritional diversity. The diversity is measured by the variety of multiple food items based on traits or nutritional components (Remans et al. 2014).
- **Education/skills** - Education is paramount in the formation of human capital. In the domain of agriculture, education may raise productivity through increased use of capital and purchased inputs (Appleton and Balihuta 1996). In this case, the level of education is a viable parameter that can be used to evaluate any direct or indirect impact of education on productivity.
- **Recreation -** In many cases, agricultural fields become a tourist destination and thus have recreational value. Recreation adds to human capital by improving people's mental and physical well-being. Therefore, this ecosystem service can be valued in monetary terms for relevant cases. The number of tourists visiting the sites can be considered an indicator of the economic value of recreation.[6]

Agricultural cost and purchased inputs

An important component in the context of agriculture is its input and maintenance costs. The objective of this study is to optimize the input cost and increase the efficiency of resource utilization. The cost of cultivation can be used to estimate the per hectare input cost from specific crops. The following components of cost are considered in this study: human labor; bullock labor; machine labor; cost of seed; cost of fertilizer and manure; cost of insecticides; irrigation charges; rental value of owned land; land revenue, cesses, and taxes; and depreciation on farm implements and farm buildings.

Residuals

Agriculture has several residues such as wastewater, crop residue, and greenhouse gas. This production system component needs to be minimized or recycled to achieve efficiency. The study acknowledges the role of residuals in achieving sustainability in agriculture and advocates low carbon pathways and recycling mechanisms as viable options to facilitate the transition. Analyzing these elements in detail for a geographical area or specific agricultural practices is a task for the future.

Agricultural and food outputs

The main provisions of agricultural output are considered here, such as crops, feed, and fisheries. There is a need to establish market linkages and incorporate value addition for agricultural outputs to raise farmers' income. However, this section emphasizes estimating the monetary returns from the agri-produce for the study site.

Agriculture produce

The provisioning of food and other agricultural produce is the major output of the agrifood system. The economic value of the produce—that is, the crops, feed (by-product), fisheries, and so on—can be estimated by using the market price method.

APPENDIX C: SCIENTIFIC & TECHNICAL ADVISORY COMMITTEE MEMBERS

A. Chairman

Dr. Ashok Khosla, Chairman, Development Alternatives Group and Board Member, WRI India, New Delhi.

B. Members

- **Mr. Siraj Hussain,** Former Secretary of Agriculture and Farmers' Welfare (GoI), Ex-CMD of FCI and Joint Secretary in DFPD, GoI, Visiting Senior Fellow at ICRIER, New Delhi
- **Dr. Suvarna Chandrappagari,** CEO, National Fisheries Development Board, GoI, Hyderabad, Telangana
- **Mr. Jigmet Takpa,** Joint Secretary and UNCCD National Focal Point, Ministry of Environment, Forests & Climate Change, New Delhi
- **Mr. Raghav Chandra**, Former Secretary, GoI, Additional Secretary and Financial Advisor, Ministry of Agriculture & Cooperation, Animal Husbandry/Dairying/Fisheries, President Society for Culture and Environment, New Delhi
- **Mr. Atul Bagai**, Head, India Country Office, UN Environment Program, New Delhi
- **Dr. Pushpam Kumar**, Chief Environmental Economist and Senior Economic Advisor, United Nations Environment Program (UNEP), Washington DC, United States
- **Dr. Suman Sahai,** Gene Campaign, New Delhi
- **Ms. Shloka Nath**, Head, Policy and Advocacy, and Sustainability and Special Projects, Tata Trusts, Acting Director, India Climate Collaborative
- **Dr. Biksham Gujja,** SRI Agri, Switzerland
- **Dr. Malla Reddy,** Director, Accion Fraterna Ecological Centre, Anantapur, Andhra Pradesh
- **Mr. Bablu Ganguly,** Chief Functionary, The Timbaktu Collective, Chennekothapalli, Anantapur District, Andhra Pradesh
- **Dr. K.S. Gopal,** Director, Centre for Environmental Concerns, Hyderabad, Telangana

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ENDNOTES

1. The income of farm households includes wages, crop cultivation, farming of animals, and non-farm business.

2. Runoff estimation from the field requires a longitudinal study with technical equipment support. For this paper specifically, secondary estimates/data have been used to derive the values and test the study framework. Therefore, field data have not been used for this study.

3. Disservices are the negative impacts (or externalities) arising from process or functions that cause direct negative effects on human well-being; for example, financial costs, loss of goods, loss of revenue, and unpleasant feelings.

4. "Social law means any law, rule, or regulation (including international treaty obligations) applicable in any jurisdiction concerning labor; social security; the regulation of industrial relations (between government, employers and employees); the protection of occupational, as well as public, health and safety; the regulation of public participation; the protection and regulation of ownership of land rights (both formal and traditional), immovable goods, and intellectual and cultural property rights; the protection and empowerment of indigenous peoples or ethnic groups; the protection, restoration and promotion of cultural heritage; and all other laws, rules, and regulations providing for the protection of employees and citizens" (Law Insider n.d.).

5. The indicator selected for women's empowerment was taken as ownership of land or rights to agricultural land, which was not included in the survey owing to human subject survey guidelines.

6. The contingent valuation method (CVM) can be used to estimate what visitors are willing to pay to access the recreational benefits of agricultural landscapes. Alternatively, the travel cost method (TCM) can be used to estimate the recreational benefits of agricultural landscapes. This method involves evaluating the travel costs and the opportunity cost of time spent visiting agricultural fields.

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ABOUT WRI INDIA

WRI India is a research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.