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Research Article

Ecosystem Service Calculator (ESS CAL): An User-friendly Interface for Quantification of Ecosystem Service Values for Wheat Crop

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ABSTRACT

As the largest engineered ecosystem, agriculture has become the world's most extensive land use, comprising over 40% of the total global land area but relying upon services provided by natural ecosystem practices. An ecosystem services calculator (ESSCAL) must be developed to quantify soil ecosystem services under different farming systems and agricultural management practices and translate the existing soil ecosystem services (or their absence) into quantifiable classes. In the research, an ecosystem service calculator was created with the goal of offering an engaging and easy-to-use tool for stakeholders to compute ecosystem services. The web application has been developed using Hyper Text Markup Language (HTML), Cascading Style Sheet (CSS) and JavaScript. The HTML is used to structure and layout the user interface (UI) of the application, which was designed to ensure a smooth user experience. Different components of UI were also created using the HTML such as navigation, menus, forms, buttons, user interaction points, etc. All the mathematical calculations and equations were implemented using the JavaScript language. The ESS CAL was developed to quantify four major categories of ecosystem services i.e. provisioning, regulating, supporting and cultural services as per Millennium Ecosystem Assessment and ecosystem disservices. Under provisioning service, it quantifies value of grain and by product yield and under regulating service it quantifies monetary value of SOC accumulation, available N, P, K, and water holding services. In case of supporting services, it considers soil formation, soil fertility, ground water recharge and biological control of pest and GHG emission and soil erosion as ecosystem dis-services. As a whole ESS CAL gives an overall outlook, that how much return from an arable agroecosystem could be obtained in monetary terms.

Key words: Ecosystem services, Monetary value, Supporting services, Regulating services

Introduction

Ecosystem is the complex of living organisms animal, plant, and microorganism), their physical environment, and their interaction as a system and ecosystem services are the benefits provided by any ecosystem to sustain and fulfil human life. Worldwide, around five billion hectares of land are used for agriculture, which constitutes about 38% of the Earth's terrestrial ecosystem. After a study published by MEA (Millennium Ecosystem assessment) 2005, ecosystem and its interaction with human welfare has gained attention. Ecosystem services (ES) can be categorized into 1) provisioning

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services i.e. food, fibre, fuel, and raw materials; 2) regulating services viz. climate regulation, regulation of water flows, and water purification; 3) supporting services are like services which are necessary for the production of all other ecosystem services like maintaining genetic and biological diversity, and 4) cultural services like recreation, scenic values, spiritual values, or values that are important for the cultural heritage or identity. These services forms basis on which regional environmental reserves and development are assessed for valuation of the ecosystem services. Agricultural and farming practices covers one third of total global area and represents the largest engineered ecosystem but relies upon services provided by natural ecosystem (FAOSTAT, 1999). Agriculture contributes towards the food security, improving livelihood and reduction of poverty (Rasheed *et al.,* 2021). Agricultural ecosystem services give health, livelihood and survival to the people and sustains live on earth. Most of the ecosystem services (ES) provided towards agriculture is through soil. Soil properties, type and variety in fertility plays an important role to determine whether farming can be taken place or not, and what will be the quality of product. It also influences the productivity of that particular crop (Freeman, 2014). Not only soil properties but also the soil fauna *i.e.,* earthworm, microorganism, micro-invertebrates *etc.* helps to improve soil properties like structure, organic matter content, fertility as well as crop production. Soil microbes (bacteria, fungi, actinomycetes etc.) improve soil fertility by inducing organic natter decomposition and nutrient recycling. However, some agricultural practices can decrease ES delivery especially by years of soil erosion, applying chemical fertilizer, pesticide, intensive soil disturbance with tillage and continuous harvest of products that remove large quantities of nutrients. The traditional methods of intensive tillage and flood irrigation for wheat rely heavily on nitrogen fertilizers, water, and machinery. This approach has led to higher greenhouse gas emissions, a drop in groundwater levels, nitrate pollution of groundwater, and largely degradation of soil and ecosystems. Over the past years, of anthropogenic activities have an extensive impact on degrading natural resources owing to higher production to feed the bourgeoning population. Humans have benefited from this transformation but at the cost of degradation of soil health for future production as well as living quality. So, there should be an alternative way of sustainable farming to restore Ecosystem services and achieve Sustainable development goal. Here, the major challenge is to develop the substitute production system that would be climate, resource, and ecosystem resilient, and can aid to sustain the crop yields in the long-run.

Recently, the valuation of ES has gained prominence in research, not only to enhance and preserve them but also to create a basis for compensating land managers who protect and maintain them Assigning a monetary value to ES is crucial for raising awareness and highlighting their importance to policymakers. In the milieu of sustainable crop production system across several environments and enhancing production efficiency, it is crucial to evaluate all ES. Given the ongoing intensification of agricultural production, this study focuses on the ES provided by any arable agroecosystem. An ecosystem services calculator (ESSCAL) must be developed to quantify soil ecosystem services under different farming systems and agricultural management practices and translate the existing soil ecosystem services (or their bsence) into quantifiable classe.

Material and Method

ESS-CAL was developed by generating data set by integrating field experiment, laboratory experiment and crude data from local market end government websites. Different soil services were categorised into four provisioning, regulating, Supporting, Cultural and ecosystem dis-services.

Total Ecosystem service = Provisioning Services+ Regulating Services+ Supporting services+ Cultural services + ES disservices

1) Provisioning Services

- Food
- By Product

2) Regulating Services

- SOC accumulation
- Available Nitrogen

- Available Phosphorus
- Available Potassium
- Water holding services

3) Supporting Services

- Value of Soil formation
- Ground water Recharge
- Value of soil fertility
- Biological Pest control

4) Cultural Services

5) Ecosystem Disservices

- Environmental cost for CO_2 emission (₹/ha)
- Environmental cost for N_2O emission (₹/ha)
- Environmental cost for Soil Erosion

Formulas and equation to obtain monetary value of ecosystem services

1) Provisioning Services

Provisioning service (₹/ha) = Value of Food + Value of by product

Value of food (₹/ha) = Grain Yield (t/ha) × Price of Grain (₹/t) (Current year MSP)

Value of by product (₹/ha) = Straw Yield (t/ha) × Price of Straw (₹/t) (current price)

2) Regulating Services

Regulating service (₹/ha) = Value of SOC accumulation + Value of Soil Available Nitrogen + Value of Soil Available Phosphorus+ Value of Soil Available Potassium+ Value of water holding service

a) Value of SOC accumulation

Price of Soil Organic carbon accumulation (₹/ha) = FYM equivalent × Price of FYM

FYM equivalent = SOC stock (Mg) / 0.16

b) Available Nitrogen

Value of Soil Available Nitrogen (₹/ha) = Price of Urea/kg × Urea equivalent

Urea equivalent = Soil available Nitrogen (kg/ha) × (100/46)

c) Available Phosphorus

Value of Soil Available Phosphorus (₹/ha) = Price of SSP/kg × SSP Equivalent

SSP equivalent = Soil available Phosphorus (kg/ha) × 2.29 × (100/16)

d) Available Potassium

Value of Soil Available Potassium (₹/ ha) = Price of MOP/kg × MOP equivalent

MOP equivalent = Soil available Potassium (kg/ha) × 1.2 × (100/60)

e) Value of Water Holding services

Value of water holding service (₹/ha) = [{Irrigation cost to apply 60 mm water (₹/ha)/60} × water holding service (mm)]

water holding service (mm)= Gravimetric water content(g/g) × Bulk Density((Mg/m^3)) × Depth of soil(m) × 1000

3) Supporting Services

Regulating service (₹/ ha) = Value of soil formation+ Value of ground water recharge + Value of soil fertility + Value of biological pest control

a) Value of Soil formation

Value of soil formation (₹/ha) = No of earthworm × 0.2 × 10^{-3} × (130/1000)

b) Ground water Recharge

Value of ground water recharge (₹/ha) = Ground water recharge (m^3/ha) × Purchase price of irrigation water (₹/m^3 water) (0.12)

Ground water recharge (m^3/ha) = {Rainfall (mm)+ Irrigation (mm)} × Coefficient of recharge (0.17) × 10

c) Value of soil fertility

Soil fertility (₹/ha) = {N-soil contribution (kg/ha) × (100/46) × 5.38} + {P-soil contribution (kg/ha) × 2.29 × (100/16) × 7.24} + {K-soil contribution (kg/ha) × 1.2 × (100/60) × 16.8}

N-soil contribution (kg/ha) = N uptake (kg/ha)- (N-fertilizer applied × nitrogen use efficiency)

P-soil contribution (kg/ha) = P uptake (kg/ha)- (P-fertilizer applied × phosphorus use efficiency)

K-soil contribution (kg/ha) = K uptake (kg/ha)- (K-fertilizer applied × potassium use efficiency)

d) Biological Pest control (₹/ ha) = (amount of pesticide × Price of pesticide) + Application cost

4) Cultural services

Value of cultural service (₹/ha) = Travel cost × No of visitors

5) ES disservices

ES disservices (₹/ ha) = Environmental cost for total GHG Emission+ Environmental cost for soil erosion

a) GHG emission

Environmental cost for total GHG Emission (₹/ha) = Environmental cost for CO_2 emission (₹/ha) + Environmental cost for N_2O emission (₹/ha)

Environmental cost for CO_2 emission (₹/ha) = - [{(Total CO_2 Emission/3.67)/1000} × 1774.25]

Total CO_2 Emission (kg CO_2-eq ha^{-1}) = CO_2 emission from Diesel+ CO_2 emission from Seed+ CO_2 emission from Fertilizer+ CO_2 emission from herbicide+ CO_2 emission from Pesticide+ CO_2 emission from electricity+ CO_2 emission from labour

CO_2 emission from Diesel (kg CO_2 -eq ha^{-1}) = {(No of tillage operation × 9) + 12 (Sowing)} × 3.45

CO_2 emission from Seed (kg CO_2 -eq ha^{-1}) = Seed rate × 1.22

CO_2 emission from Fertilizer (kg CO_2 -eq ha^{-1}) = Nitrogenous fertilizer applied (kg N/ha) × 4.77+Phosphatic fertilizer applied (kg P/ha) × 0.73 +Potassic fertilizer applied (kg K/ha) × 0.55

CO_2 emission from herbicide (kg CO_2 -eq ha^{-1}) = Amount of herbicide applied (kg ai/ha) × 6.3

CO_2 emission from Pesticide (kg CO_2 -eq ha^{-1}) = Pesticide applied (kg ai/ha) × 5.1

CO_2 emission from electricity (kg CO_2 -eq ha^{-1}) =Total irrigation applied (mm) × 0.106

CO_2 emission from labour(kg CO_2 -eq ha^{-1}) = No of man days × 0.86

Environmental cost for N_2O emission (₹/ha) = - [{(Total N_2O Emission /3.67)/1000} × 1774.25]

Total N_2O Emission (kg CO_2 -eq ha^{-1}) = Direct N_2O emissions (kg CO_2-eq ha^{-1}) + $N_2O_{volatilized}$ (kg CO_2-eq ha^{-1}) + $N_2O_{leached}$ (kg CO_2-eq ha^{-1})

Direct N_2O emissions (kg CO_2-eq ha^{-1}) = [Rate of nitrogenous fertilizer applied (kg ha^{-1}) + {Amount of residue applied (kg/ha) × N% in residue} / 100] × 0.007 × $\frac{44}{28}$ × 298

$N_2O_{volatilized}$ (kg CO_2-eq ha^{-1}) = Rate of nitrogenous fertilizer applied (kg ha^{-1}) × 0.1 × 0.010 × $\frac{44}{28}$ × 298

$N_2O_{leached}$ (kg CO_2-eq ha^{-1}) = Rate of nitrogenous fertilizer applied (kg ha^{-1}) × 0.3 × 0.0075 × $\frac{44}{28}$ × 298

b) Soil Erosion

Environmental cost for soil erosion (₹/ha) = - [130×{Soil erosion (t/ha/yr) × 0.3}]

Development of user interface "Ecosystem service calculator (ESS CAL)"

In the study an ecosystem service calculator was developed which aims to provide an interactive and user-friendly tool for calculation ecosystem services for the stakeholders. The web application has been developed using Hyper Text Markup Language (HTML), Cascading Style Sheet (CSS) and JavaScript. The HTML is used to structure and layout the user interface (UI) of the application, which was designed to ensure a smooth user experience. Different components of UI were also created using the HTML such as navigation, menus, forms, buttons, user interaction points, etc. The CSS was utilized for styling and ensuring a responsive and visually appealing design of the user interface. And finally, the JavaScript was used to implement client-side scripting to enable interactive functionalities such dynamic content, form validation. All the mathematical calculations and equations were implemented using the JavaScript language.

Result and Discussion

Using the above-mentioned methodology ESS CAL was developed to calculate the economic value of ecosystem services from an arable agroecosystem. The Ecosystem Service Calculator (ESS CAL) was effectively developed as an interactive, web-based instrument to quantify and monetize the extensive range of ecosystem services (ES) obtained from arable agroecosystems associated with wheat farming. The ESS CAL web interface, constructed with HTML, CSS, and JavaScript, exhibited efficient functionality in facilitating sequential, user-directed

Provisioning services

Fig. 1. Quantification of provisioning services

Regulating Services

Fig. 2. Quantification of provisioning services

Supporting Services

Fig. 3. Quantification of supporting services

Cultural services

Fig. 4. Quantification of supporting services

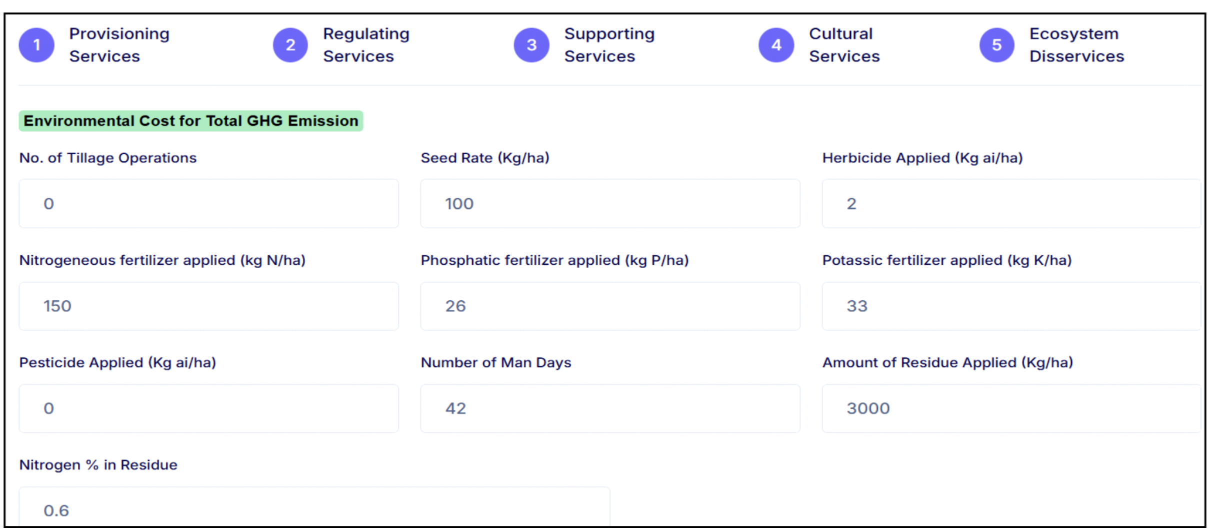
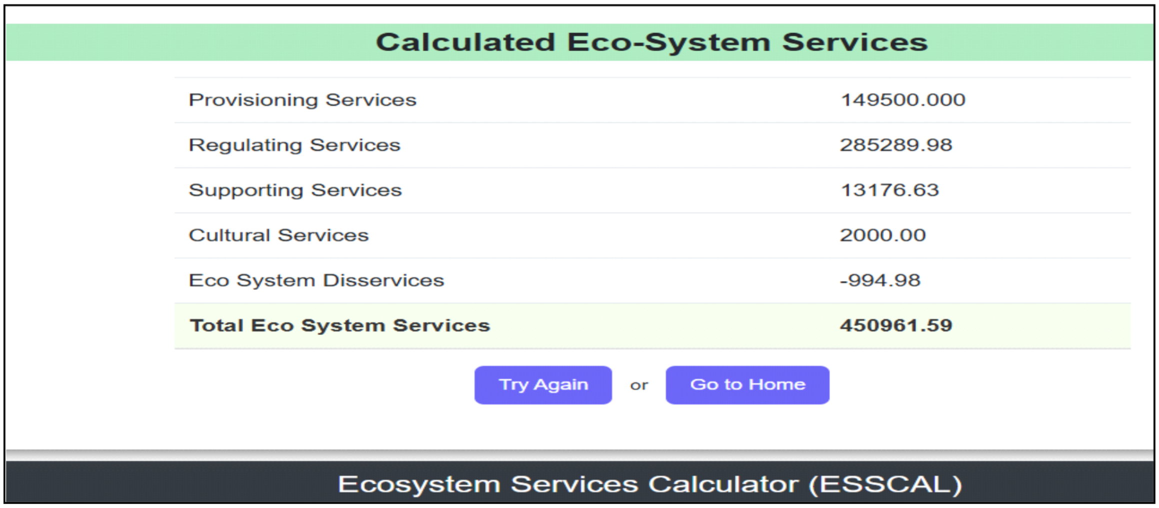


Fig. 5. Quantification of Ecosystem Dis-services

Total Ecosystem services



Provisioning Services	149500.000
Regulating Services	285289.98
Supporting Services	13176.63
Cultural Services	2000.00
Eco System Disservices	-994.98
Total Eco System Services	**450961.59**

Fig 6. Quantification of Total Ecosystem services

data entry and automated computation across all five ES modules. The modular tab-based architecture (Figs. 1–6) guarantees easy navigation and accessibility for non-specialist stakeholders such as farmers, extension workers, and policymakers, achieving the tool's primary design goal of ecosystem service value at the field scale. The implementation of replacement cost and market pricing methodologies inside a cohesive digital platform signifies a pragmatic and scalable improvement over the manual or spreadsheet-based ES accounting methods currently dominant in the Indian agriculture context. The calculator incorporates all four primary ecosystem service categories as delineated by the Millennium Ecosystem Assessment (MEA, 2005): provisioning, regulating, supporting, and cultural services, in addition to ecosystem disservices (EDS), offering stakeholders a comprehensive and monetarily quantified perspective on agroecosystem performance.

Conclusion

This study proposes the framework to quantify the economic valuation of marketable (provisioning ES) and non-marketable ES (regulating ES, supporting ES, cultural ES and EDS) from the arable agroecosystem. ESS CAL could be used to quantity the monetary return from an agroecosystem and a payment based scheme to sustain ecosystem could be formulated.

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