Perspective

True Cost Accounting of Food Using Farm Level Metrics: A New Framework

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Abstract: The application of true cost accounting (TCA) at farm level requires a common framework and metric for measuring, capturing and valuing sustainability. We propose such a framework and farm metric that build on the four capitals—natural, social, human and produced—that are essential for sustainability. The framework is developed by reviewing the scientific and technical literature on various approaches and tools that have been used to measure farm sustainability. We use quantifiable aspects of sustainability in the farm metrics. The farm sustainability metrics comprise four capitals with 11 categories and 33 indicators. These indicators can be assessed using bio-physical assessment, descriptive or quantitative methods. Once this information is compiled for a farm, then some of the categories can be monetised to reflect all the costs and benefits of using state-of-the-art TCA. There is a need to establish benchmarks and standards for each of the four types of capitals and indicators for the comparison of food systems. We believe the use of this comprehensive framework and farm metrics will help to correct several deficiencies of the current food system. We conclude by highlighting the benefits and limitations in the use of farm metrics. Measuring all positive and negative externalities at farm level can shift global food systems towards sustainability.

Keywords: farm sustainability; TCA; natural capital; social capital; human capital

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1. Introduction

Global food systems are able to produce sufficient food to meet the calorific demand for the current human population. However, about 690 million people do not have access to food, and 2 billion do not have regular access to nutritious food [1]. There is growing awareness that the global agriculture and food systems will not be able to meet the targets set up by the United Nations' Sustainable Development Goals (SDGs) in meeting the demand for safe, healthy and nutritious food by more than 9 billion people by 2030 [2,3]. It is also realised worldwide that the food systems that include production, processing, distribution and consumption have massive impacts on the environment and climate [4]. For example, a third of global greenhouse gas emission comes from food systems, they cover 38% of the Earth's terrestrial surface, consume more than 70% of global freshwater, and one third of all food is not eaten but wasted [2,5–7]. In order to meet the global targets of healthy and safe food for all, and by maintaining environmental sustainability, there is a need to address food systems more holistically. This has potential to address global climate change and will also help achieve the SDGs related to food. In order to address food systems more holistically, there is need to measure, capture and value the sustainability of food systems [2]. Here, we provide a new framework to measure, capture and value sustainability at farm level as a proof of concept for the application of true cost accounting (TCA) of food. In this study, we use a farm as the smallest functional unit of the global food system to demonstrate the application of TCA.

The term ‘food systems’, “encompasses the entire range of actors and their interlinked value-adding activities involved in the production, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal, and natural environments in which they are embedded” [8] (p. 1).

Current agricultural and food systems have been designed to maximise per hectare productivity by using a large amount of agrochemicals and energy inputs. They aim to maximise profits. However, such production systems (i) do not value the contribution of ecosystem services, (ii) often overlook social capital in agriculture, and (iii) fail to address the negative impact of intensive practices on ecological health. Such systems may increase production and profits, but they negatively impact social and natural capital as compared to some of the sustainable alternatives [9,10]. Such high input–output-based food production systems are also supported by the current economic and policy environment.

Therefore, there is need to understand, assess and monetise all costs and benefits of different types of food production systems. This information then can be used to develop more sustainable food systems by appropriate policy response.

2. Background

There has been several initiatives and frameworks that have been developed at the global, national, and landscape scale to recognise and value the benefits that biodiversity provides to people, by including natural capital into national accounting process. These are summarised in Table 1.

Table 1. An overview of approaches and tools to measure sustainability.

Initiatives/ Assessments	Millennium Ecosystem Assessment [11]	Recognition of the Importance of Ecosystem Services in Providing Life Support Functions of the Planet
	The Economics of Ecosystem Services and Biodiversity (TEEB) [12]	Value of ecosystems and biodiversity in global economy.
	The Economics of Ecosystem Services and Biodiversity in Agriculture and Food systems (TEEBAgriFood) [2]	Value of nature, social capital, human skills and knowledge, public health in agriculture and food systems.
	IPBES [13]	Global assessment of nature’s contribution to people.
	System of Environmental-Economic Accounting [14]	Accounting for environmental pollution, land use change, anthropogenic emissions in national accounts.
	The Dasgupta Review [15]	Economics of biodiversity.
Tools	Ecological Footprint [16]	The quantity of natural resources required to support people or an economy.
	Life Cycle Analysis [17]	It evaluates the life cycle of a product by measuring the environmental impact throughout its value chain stages, including final disposal and recycling. It also includes measuring impacts such as the extraction of resources required to produce that product.
	Life Cycle Costing [18]	It includes all stages of the value chain. It includes production, processing, manufacturing, distribution, consumption and recycling. This approach is focused on the use of resources and reflects both internal and external costs. Internal costs include the cost of materials, energy, labour, capital, etc., whereas external costs include the environmental impact of the processes, the cost of pollution, the cost of health problems and the social cost.

Table 1. Cont.

Initiatives/ Assessments	Millennium Ecosystem Assessment [11]	Recognition of the Importance of Ecosystem Services in Providing Life Support Functions of the Planet
	Activity-Based Costing [19,20]	It includes the costs of each activity that is required to produce a product. This approach helps to divide environmental costs (by products), the composition of the environmental costs and strengthen the environmental cost management of the operations.
	Material Flow Costing [21]	It measures the flows and stocks of materials in manufacturing. It produces accounts in both physical and monetary units. Material cost accounting helps organisations to improve their business efficiency and reduce environmental impacts.
	Environmental Management Accounting [22–24]	A system that explicitly includes all direct and indirect costs and benefits of a transaction. Most of the tools in EMA measures the direct costs of pollution but full cost accounting includes indirect costs as well. These indirect costs and benefits are incurred by the direct beneficiaries or any third parties involved in a transaction. It includes conventional business costs, environment costs and social costs of product or services.
	Full Cost Accounting [25]	An accounting method to assess the social, economic and environmental performance of an organisation. It includes both financial and non-financial performance and allows organisations to look at their business from five perspectives; economic, social, internal business, learning and growth and environmental.
	TCA [10,26,27]	It is defined as an approach to understand the positive and negative impacts of food systems on the natural environment, society, and the economy.

Out of the above approaches, the Economics of Ecosystem and Biodiversity in Agriculture and Food systems (TEEBAgriFood) provides a comprehensive approach to analyse costs and benefits of global farming and food systems [2]. There are several tools that have been developed to assess the impacts of food systems, as summarised in Table 1. However, there is lack of a single farm-based evaluation framework and metric that can measure, capture and demonstrate all costs and benefits across all four capitals—produced, social, human and natural.

Here, we propose a new framework to measure, capture and value sustainability using farm metrics as an application of the TCA of a food system.

Economic Foundations of TCA

TCA approaches are trans-disciplinary in nature as they are derived from the principles of ecological economics [27]. TCA is based on the principles that our economic system is embedded in the natural environment. TCA is often described as a critical tool or a mechanism to understand the impacts and dependencies, both positive and negative, of food systems on people, their health, natural environment and economic system [28]. The main aim of TCA in food systems is to create just and fair food systems that meet the current need for food and also meet the future need by promoting the sustainable use of resources. TCA analysis can be applied to assess agri-products, compare different diets, farming systems, farm and food policies, and national accounts or corporate balance sheets [2,3]. The TCA approach does not necessarily mean monetising all the costs and benefits associated with food systems. However, it has evolved over a period of time by improving the environmental-accounting approaches and can be used to monetise several externalities.

3. Farm Sustainability Framework

In order to apply TCA in food systems, there is a need to first develop a comprehensive farm-based sustainability framework and metric. We use a bottom-up approach to develop this new framework. The bottom-up approach is farm-centric and is based on three—technical, geographic, and social—indicators. The environmental, economic, and social sustainability of food systems depend on these three fundamental indicators [29]. It is based on the premise that if all the costs and benefits of a farm are known or can be calculated in terms of biophysical, descriptive, or monetary units, then we will be able to form a better understanding of the farm sustainability. This information then can feed into the local economy, supply chains, retails, agribusiness, supermarkets and eventually into national accounts. This can be scaled up to form a global understanding of all costs and benefits of the remaining food value chain—processing, manufacturing, transport, consumption. Incentives for generating public goods and services or penalties for degrading them can then flow from top-down towards supporting farm sustainability.

Therefore, we have chosen a farm as the smallest unit in the global food systems to apply TCA in food systems. There are 570 million farms around the world that form the basic functional unit in the global food system.

We reviewed the scientific and technical literature to identify various tools that are available to assess sustainability at farm level [30,31]. There are about 100 tools that are currently available to assess various aspects of agricultural sustainability [30,31]. They differ in the use of scope, methods and frameworks. Some of the commonly used methods are LCA used by the Cool Farm Tool (CFT) [32], multi criteria analysis used by Response Inducing Sustainability Evaluation (RISE) [33] and Public Goods (PG) [34] tools, triple bottom line (TBL_ by PG Tool and Sustainability Assessment of Food and Agriculture Systems (SAFA) [35], ecosystem services assessment by the healthy farm index, and Integrated Evaluation of Ecosystem Services and Tradeoffs (InVEST) [36]. These tools capture key aspects of social, environmental and economic dimensions of farming [31]. These tools are able to capture and assess bio-physical aspects of farming and food more comprehensively but fall short on monetising any costs and benefits. In addition, these tools are developed to be used as a top-down approach to assess farm sustainability by industry or government for specific purposes. These purposes could vary from incentivising farmers to produce more production or nutrition or improving one or more aspects of environmental indicators. Therefore, each time, farmers would use a different tool for a different purpose. Therefore, the farm metric is being developed to overcome some of the shortcomings of the existing tools. It goes beyond capturing bio-physical aspects and provides the outputs in a format that can be monetised using TCA to reflect key costs and benefits of the food production system in the farm accounts. Farmers and farm managers often have to supply farm data in different formats using multiple tools for the purpose of certification (for organic), direct payments (to receive farm payment from the government) and agri-environment schemes. The farm metrics developed here respond to the need for convergence between various tools and data collection methods. The SAFA framework and TEEBAgriFood frameworks are used to develop this converged farm metric to reflect all relevant aspects of farm sustainability. The reporting format is based on SAFA as it allows farmers and farm managers to easily comprehend the results [35]. Other commonly used tools such as CFT, PG, RISE, etc. use lengthy reports to interpret the results [31].

Based on our review, we identified 11 broad categories that are aligned to natural, social, human and produced capital as suggested by the TEEBAgriFood study. These are summarised in Table 2.

Table 2. A new framework and metrics to assess farm sustainability.

Capital	Weights	Category	Indicator	Description	Sub-Indicator	Sub-Weights	Method for Assessment
Natural capital	0.25	Soil	Soil organic matter	Organic matter in soil that is critical for maintaining soil structure, biodiversity and function such as storing nutrients and accumulating carbon	Soil organic carbon	2.08	Bio-physical assessment
			Biodiversity	Micro and macro diversity in soil that is essential to perform soil functions	Faunal diversity, macro and microbial	2.08	Bio-physical assessment
			Structure	Physical and chemical properties of soil	Available water capacity (mm)/tillage type/land use classification	2.08	Bio-physical assessment
		Air and climate	Emissions by source	Greenhouse gas emissions from the use of machinery, energy, livestock and all other farm-related activities	CO ₂ e (tonnes/acre)	2.08	Bio-physical assessment
			Carbon sequestration	Potential to sequester carbon in soil, above ground and below ground vegetation	CO ₂ e (tonnes/acre)	2.08	Bio-physical assessment
			Nutrient balance	Emissions from nutrient use to be estimated as carbon dioxide equivalents	CO ₂ e (tonnes/acre)	2.08	Bio-physical assessment
		Biodiversity	Agriculture	Crop biodiversity on farm	Crop diversity	2.08	Bio-physical assessment
			Natural	Animal biodiversity on farm	Diversity/rare breeds/local breeds	2.08	Bio-physical assessment
			Landscape	Diversity of natural elements on the landscape	Conservation area/wetlands/hedgerows	2.08	Bio-physical assessment

Table 2. Cont.

Capital	Weights	Category	Indicator	Description	Sub-Indicator	Sub-Weights	Method for Assessment
		Water	Source	Sustainable source of water	Groundwater/surface water/rainwater	2.08	Bio-physical assessment
			Quality	Biological, physical and chemical properties of water	% nutrients in water	2.08	Bio-physical assessment
			Sedimentation	Catchment management	Protection measure/dams	2.08	Bio-physical assessment
Produced capital	0.25	Energy and resource use	Energy usage/mix	Source of energy use on farm	Renewable/non-renewable	1.67	Bio-physical assessment
			Energy self-sufficiency	Energy generation on farm	Wind/biomass/solar	1.67	Bio-physical assessment
			Waste/recycled material	Recycled material use	Usage/recycling	1.67	Bio-physical assessment
		Plant and crop health	Pest and disease management	Type of management regime	Organic/agrochemicals	1.67	Bio-physical assessment
			Crops grown and rotation	Crop type and rotations	Crop-legume-crop/crop-crop/crop-pasture	1.67	Bio-physical assessment
			Nutritional quality	Quality, safety of produce	Nutritional food	1.67	Bio-physical assessment
		Livestock management	Management system	Management regime for livestock	Mixed, intensive, organic, etc.	1.67	Bio-physical assessment
			Nutrition and input efficiency	Animal feed source	Grazing/feed	1.67	Bio-physical assessment
			Diversity, health and welfare	Animal welfare	Open days/indoor	1.67	Bio-physical assessment
		Productivity	Physical output	Physical output of farm	Quantity	1.67	Bio-physical assessment
			Financial output	Net returns	Profits	1.67	Monetary units
			True cost balance sheet	Adjusted profits after accounting for all externalities	Costs and benefits	1.67	Monetary units
		Nutrient management	Nutrient balance sheet	Status of nutrients in soil and plants	Soil/plant nutrients	1.67	Bio-physical assessment
			Management efficiency	Resource use efficiency	Application methods	1.67	Bio-physical assessment

Table 2. Cont.

Capital	Weights	Category	Indicator	Description	Sub-Indicator	Sub-Weights	Method for Assessment
Social capital	0.25	Social capital	Inputs/outputs	Balance in inputs and outputs	Balance	1.67	Bio-physical assessment
			Health	Perceived health impacts on community	Community health	8.33	Quantitative, Descriptive
			Community engagement	Farm networks and participation in local farming community	Networks	8.33	Quantitative, Descriptive
			Education	Participation of farm in science and education	Science, research participation	8.33	Quantitative, Descriptive
Human capital	0.25	Human capital	Health of workers	Health impacts of farmers and farm workers	Welfare	8.33	Quantitative, Descriptive
			Skills and knowledge of farm workers	Professional qualifications of farm workers	Technical or professional training	8.33	Quantitative, Descriptive
			Employment	Fair wages, benefits of farm employees	Wages, recreation leave, benefits	8.33	Quantitative, Descriptive

The farm sustainability metrics comprise four capitals with 11 categories and 33 indicators [31]. These indicators can be assessed using bio-physical assessment, descriptive or quantitative methods. Quantitative methods are used to establish equal weights for each of the four types of capitals. Sub-weights are equally divided within each capital for various indicators. Once this information is compiled for a farm, then some of the categories can be monetised to reflect all costs and benefits while others can be described to represent the level of farm sustainability. Farm metrics describe four capitals as stocks accumulated over time and form the foundation of a functional farm. Flows of these capitals can be described in the form of ecosystem services for natural capital as positive impacts or benefits, agricultural inputs and output for produced capital as benefits, and any residual flows such as pollution and greenhouse gas emissions to capture negative impacts. Each of the four capitals and corresponding indicators are described below and summarised in Table 2.

3.1. Produced Capital

Produced capital includes agricultural inputs and outputs, including financial capital, and can be measured by using farm accounting standards by using definitions from the System of National Account. The concept of produced capital in agriculture and food systems is based on the TEEBAgriFood report [2,37]. It includes energy and resource use, plant and crop health, livestock management, farm productivity and nutrient management. Farm metrics include six indicators: energy and resource use, plant and crop health, livestock management, productivity, and nutrient management.

3.2. Natural Capital

Natural resources on a farm such as air, water, soil, biodiversity form the natural capital associated with food production. Natural resources can be measured by using the System of Environmental–Economic Accounting [14]. Flows of natural capital include ecosystem services. Residual flows include emissions, water and soil pollution, etc.

Social capital in food systems include various networks of farmers, producers, market networks, community health, etc. that enable growers to respond as a collective to become more effective [38]. Social capital is based on trust, common rules, and norms and can be measured by assessing these inter-connections [39]. In farm metrics, it includes community health, engagement and education.

Human capital in food systems includes the health of farmers, farm workers, factory workers, processors, and their knowledge, skills and motivation. It also includes opportunities for gainful employment. It is based on the premise that food systems benefit from investments in people's skills and their health [40,41].

The farm sustainability framework provides a comprehensive assessment of a farm to develop better understating of the food systems. As summarised in Table 2, we assume that all four categories carry equal weights and there is a market incentive to maintain or enhance natural, social and human capitals alongside produced capital (Figure 1). Within each of these four capitals, weights are equally distributed for various indicators to reflect a comprehensive sustainability score. These weights should be held constant while discussing the incentive schemes with the decision makers, who could be market, consumers, government, etc. There is a need to first generate a benchmark for each of the indicators and capital so that different farms can be assessed to receive public or private benefits. For example, to assess natural capital/soil, three indicators can be tested, as shown in Table 3. Soil organic matter, biodiversity and structure have equal weights. A further final score can be assigned based on the bio-physical assessment of these three indicators per farm or site. Similarly, other categories can be worked out to generate a final score per farm that can be compared with neighbouring or other farms to receive market or policy incentives if they perform above the benchmark. The benchmark could be established by review of the scientific literature and in conjunction with primary biophysical assessment of natural resources in various agri-eco regions. Policy and market both need to work together to establish benchmarks for these categories for different type of farms and regions through spatial and temporal assessments.

Table 3. Application of farm metrics as an example of soil as natural capital.

[illegible]

Figure 1. Farm metrics showing all four capitals, categories and indicators with equal weights to assess sustainability.

5. From Farm Metrics to TCA

Some of these indicators can then be used to aggregate all costs and benefits per farm [40]. TCA does not always involve monetised value but can be a descriptive or quantitative account of various categories in four capitals [10]. This will show if the overall farm performance has a positive or negative impact in all four capitals.

We anticipate that with the adoption of this novel, universal, and harmonised framework, farm sustainability will improve and also policy support from market and public policy can be better channelised to support better farm practices. While the metrics applied at farm scale is a bottom-up approach and can feed into global food systems, the incentives are top-down and need to reach out to farm from local or national food policy.

Sustainable agriculture and food systems can be developed by identifying and reducing all externalities by using this farm sustainability framework. This can be then used by national policy to incentivise agricultural practices that are less detrimental to the environment and human health and to penalise those that have high impacts.

The major output of applying this framework is to reveal the value of social and environmental benefits of sustainable food production along with any social and environmental costs of different food production systems. The agriculture and food industry will be able to see all hidden costs associated with the food production throughout the value chain and take necessary action to monitor and reduce them. The intended outcome is that farmers, farm managers, consumers and retailers can make better decisions on the basis of these economic values regarding their food production and consumption choices [27]. This information can then help producers to optimise benefits and minimise negative externalities; once the values are known, retailers can use this information in marketing sustainably grown produce by informing consumers about how (and how much) they minimise impacts on the environment and natural resources, and consumers can make better informed decision for themselves in making food choices [27].

The proposed framework is a comprehensive and up to date approach that can be used from the farm scale to the national policy level. However, there are several limitations and challenges in the use of this framework. One of the key challenges is data source and

data collection. A process to streamline data collection is required with some uniform standards at local, regional and global scale. The farm sustainability framework and metric can be useful for producers, supermarkets, agribusinesses and governments. However, there are challenges in scoping each study based on its target audience. If farmers want to use it to correct their detrimental farming practices, then the scope is limited to the farm scale. In contrast, if a supermarket wants to raise awareness of the food that they sell, they need to have wider scope for applying this framework.

Currently, some market provides incentives to organic food with premium prices that are paid by consumers. Beside this there are no such incentives at farm, market or national agricultural policies to apply TCA and to understand impacts.

Consumers are not aware of all the impacts of food systems. However, there is increase in number of consumers who demand full disclosure in how food is produced. TCA can help them to understand these impacts and then support food products that are less damaging. However, there is need to raise awareness amongst consumers about the utility of TCA as a comprehensive tool [10,27].

A lack of policy at national and global level also means there is no existing national or international accounting framework to advance the use and implementation of TCA through the value chain of each agriculture and food product.

6. Conclusions

We have developed a farm sustainability metric comprising four capitals—natural, produced, social and human—with an aim to apply TCA to food systems. This will help to identify the hidden costs of food production systems. TCA is being perceived as an approach as well as a tool to reveal hidden social and environmental costs of food systems. We have provided an application of TCA to farm level to develop this new framework. We also highlight that the application of this framework is challenging as it requires multi-dimensional data on environmental, social and health indicators, which may limit its use. Moreover, there is no current benchmark to compare sustainability across several farms or farming systems. We speculate that the widespread use of this metric will help users, researchers and practitioners to generate sufficient outputs to establish benchmarks. The farm sustainability framework proposed here is based on a comprehensive systems approach and builds on the existing environmental cost accounting framework and extends its scope to include social, human and health impacts in addition to environmental impacts in order to develop more sustainable agriculture and food systems. Some of the challenges and shortcomings in earlier tools, approaches, frameworks are addressed in the development of this metric [30,31,40]. The development of this framework is a first step in advancing the methodology to analyse farms to better understand and improve them. The further development of international standards followed by policy response through appropriate market incentives and national agriculture policies will help in the adoption of TCA applications more widely. This has the potential to assist the global community with operating agriculture and food systems within the planetary boundaries and advancing the wellbeing of farming communities around the world. Recognising and measuring all positive and negative externalities is not an end but a beginning towards more equitable and sustainable food systems.

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