CHAPTER 8

APPLICATION OF THE TEEBAGRIFOOD FRAMEWORK: CASE STUDIES FOR DECISION-MAKERS

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SUMMARY

Chapter 8 demonstrates an initial exploration of the TEEBAgriFood Evaluation Framework through ten existing case studies that focus on various aspects of the value chain: agricultural management systems, business analysis, dietary comparison, policy evaluation and national accounts for the agriculture and food sector. Various issues within the Framework are explored, including the need for future modifications and adaptations. The case studies have helped identify opportunities to both expand particular aspects of the Framework for comparisons as well as to introduce spatial and temporal contexts. The explorations within this chapter are an introduction to a process that will continue to expand, as lessons are learned with each application of the Framework.

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CHAPTER 8

8.0 KEY MESSAGES

- Chapter 8 demonstrates an initial exploration of the TEEBAgriFood Evaluation Framework through ten existing case studies that focus on various aspects of the value chain: agricultural management systems, business analysis, dietary comparison, policy evaluation and national accounts for the agriculture and food sector.
- Various issues within the Evaluation Framework are explored, including the need for future modifications and adaptations. The case studies have helped identify opportunities to both expand particular aspects of the Framework for comparisons as well as to introduce spatial and temporal contexts. With each application and adaptation of the Framework, it becomes robust and comprehensive. Thus, the explorations within this chapter are an introduction to a process that will continue to expand as lessons are learned with each application of the Framework.
- The chapter illustrates how the Framework can be adapted to capture all stocks and flows of natural, human and social capital through the entire value chain of eco-agri-food systems so that they can be better reflected in national accounts.
- There is need to extend the scope of the Framework to examine trade-offs at each stage of value chain as found in various examples, especially when comparing management systems and evaluating policy scenarios.
- There is no single example included where the entire value chain was explored; therefore, there is a compelling case to develop and apply the TEEBAgriFood Framework further in order to better understand all positive and negative externalities in an eco-agri-food system complex.
- A comprehensive and full-scale application of the TEEBAgriFood Framework can help address policy questions. For example, to help determine the best agricultural management system, the Framework can help analyse contrasting systems, which can help develop policy responses that incentivise better management. The Framework can be used by consumers to weigh dietary choices and better understand the health implications of their current food consumption patterns, and to evaluate food footprints.
- There is need to redefine priorities and plan further testing of the Framework in order to better consider entire value chain and to better evaluate capital (natural, social, human) and stocks (flow of ecosystem services) in the agriculture sector. Complete application will require a considerable amount of time and resources to populate the Framework. A limited number of case studies are explored here due to data restrictions.

CHAPTER 8

APPLICATION OF THE TEEBAGRIFOOD FRAMEWORK: CASE STUDIES FOR DECISION-MAKERS

8.1 INTRODUCTION

This chapter seeks to help navigate the complexity of contemporary eco-agri-food systems and to assess their many dimensions, taking account of both positive and negative externalities (social, human and environmental) as well as ecological dependencies. The preceding chapters have provided the TEEBAgriFood Evaluation Framework (Chapter 6) and reviewed diverse methods of valuing and evaluating sustainability in the eco-agri-food value chain (Chapter 7). In this chapter, we present five distinct "families of application" for which the Framework could be useful, and needs adaptation for at least five groups of stakeholders (See **Table 8.1**). The five families are: i) agricultural management systems which are defined by the type of practices and production systems at farm level and may include organic, conventional, natural farming, high or low input systems, ii) agricultural products include analysis of farm products such as organic milk and conventionally produced milk, iii) dietary comparisons family include diverse set of diets, for example, Mediterranean diet, plant based diet, vegetarian diet, iv) policy evaluations include different farm and agricultural related public or business sector policies at national, global or regional scale, and v) national accounting applications may examine differences between standard national accounts and adjusted national accounts after internalising externalities.

At this early stage in the development of TEEBAgriFood as an approach, complete examples of the application of the Framework do not exist. We have thus sought to present in **Table 8.2** a snapshot of ten case studies[1], illustrating a diversity of approaches that seek to assess different aspects (i.e. positive and negative externalities) of the eco-agri-food value chain in a range of different geographic contexts. In some cases, existing studies provide sufficient detail to be mapped onto the Framework directly, showing how it can be applied or adapted. In other cases, it was necessary to carry out a review of the literature and bring additional information into the case study from other sources, in order to explore the utility of the Framework.

Table 8.1 Five "families of application" as identified by TEEBAgriFood, and their relevant stakeholder groups

Family of application	Stakeholders
Agricultural management systems	Agricultural producers, Farming communities, Consumers and public, Policy makers
Agricultural products	Agricultural producers, Farming communities, Consumers and public, Policy makers
Dietary comparisons	Consumers and public, Policy makers
Policy evaluations	Public, Policy makers
National accounting for the agriculture and food sector	Public, Policy makers (at national level)

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[1] Full details of each case study are provided in a separate Annexure, available online at www.teebweb.org/agrifood/scientific-and-economic-foundations/chapter-8-annexure.

Table 8.2 A snapshot of the ten case studies presented in this chapter

Family of application	Case study	Aspects along agri-food value chain	Comparison	Geographic scope	Valuation methods and evaluation models
Agricultural management systems	1. Rice management practices	Agricultural production	Ecosystem functions, services and impacts at farm and landscape level under agroecological versus conventional rice management systems and practices	Philippines, Cambodia, Senegal, USA, Costa Rica, Vietnam, Malaysia, Indonesia	Direct market valuation, multi criteria analysis, cost benefit analysis
	2. Organic and conventional agriculture	Agricultural production	The value of a suite of ecosystem services under different management systems	New Zealand, Global	Direct market valuation, production function approach, avoided cost
Agricultural products	3. Beef production-grass fed versus grain fed	Agricultural production, manufacturing, Distribution	Impacts and benefits of different beef production systems, at farm, processing and consumption levels	United States	Direct market valuation, market price
	4. Palm oil study	Agricultural production, manufacturing	Key natural capital impacts of palm oil production	11 leading producer countries	Market price, avoided cost, damage cost, integrated approaches (Life cycle analysis)
Dietary comparisons	5. Welfare and sustainability effects of diets	Household consumption	Multiple sustainability dimensions of dietary recommendations	France	Life cycle analysis, cost benefit analysis, avoided cost
	6. Ten different diet scenarios ranging from meat based to vegetarian diets	Agricultural production, Manufacturing, Distribution, Household consumption	Bio-physical impacts of different diets on land use and carrying capacity	United States	Land use and biophysical models, Life cycle analysis
Policy evaluations	7. Pesticide tax case study	Agricultural production, Household consumption	External costs of pesticide, as could be used to inform policy	Thailand	Dose response function, Partial equilibrium model
	8. China Ecosystem Assessment	Agricultural production	Reduction of natural disaster risk by restoring forest and grassland, impacts on livelihood options and poverty	China	Direct market valuation, bio-physical models, InVest model
National accounting for the agriculture and food sector	9. Agricultural development in Senegal	Agricultural production, Manufacturing, Distribution, Household consumption	Socio-economic and environmental impacts of investment in different types of agriculture development	Senegal	System dynamics and biophysical models, cost benefit analysis
	10. Environmental-economic national accounts	Agricultural production, Manufacturing, Distribution, Household consumption	Biophysical costs and benefits of the agriculture sector	Australia	Market price methods, Computable General Equilibrium

8.1.1 Commentary on the evolving nature of the TEEBAgriFood Evaluation Framework

This chapter presents lessons learned from drawing on existing evidence and studies to populate the TEEBAgriFood Evaluation Framework, with reference to the five "families" of application described above. The case studies presented here demonstrate both the potential and the limitations of the Framework, notably with respect to spatial and temporal dimensions. With each application and adaptation of the Framework to specific circumstances, the Framework should become more robust and comprehensive. The exploration in this chapter may be seen as part of a process that will continue, as further lessons are learned with each application.

The rest of the chapter is organised as follows. Section 8.2 provides the scoping criteria and data collection process and explains how each example was selected, Section 8.3 summarises the ten applications under five different families and reviews the lessons learned from the application of the Framework, Section 8.4 highlights social inequities, Section 8.5 provides challenges and limitations of the Framework, and Section 8.6 offers some closing thoughts. It should be noted that all Tables featured in this chapter have been generated by the authors.

8.2 APPLYING THE TEEBAGRIFOOD EVALUATION FRAMEWORK

The TEEBAgriFood Framework facilitates the comparison of systems that generate ecosystem services - the goal being to minimize negative externalities and facilitate positive ones – thereby contributing to increases in stocks of produced, natural, human and social capital, and thus to human well-being. A comprehensive listing of ecosystem services can be found in many recent texts including the TEEB (2010) and, more recently, CICES (EEA 2018). TEEBAgriFood thus seeks to focus on the capacity of different systems in the agriculture and food sector to contribute to increases in stocks of produced, natural, human and social capital, thus to human well-being.

8.2.1 Scoping and criteria

Selection criteria

A criterion for the selection of examples described in this chapter is found in **Table 8.3.** First, the intention was to examine studies that captured all positive and negative externalities of the eco-agri-food system and was not solely focused on productivity. For example, if a given study examined different management systems and provided both monetary and non-monetary (bio-physical) estimates of impacts, then we selected it for further analysis. In addition, we focused on studies that examined changes in stocks of produced, social, human or natural capital and that studied the impacts on human well-being. We carefully searched for and selected examples that fall under one of the five families of applications of the framework – management systems, food products, different diets, policies, and national accounts. We also looked for examples that captured externalities of at least one aspect of the value chain (i.e., production, manufacturing, distribution and household consumption) in detail.

The ten case studies used various valuation methods and evaluation models, which are listed at the beginning of the case study and described in detail in the previous Chapter 7.

Case studies described in this chapter were selected during a two-round process. First, all shortlisted examples were evaluated using the selection criteria in **Table 8.3.** Then they were further examined using in-depth criteria in **Table 8.1** These set of criteria were used to make a comprehensive decision on the selection of cases, to ensure a high quality and diversity of the examples.

We considered geographic balance and selected examples covering Africa (Senegal), Oceania (Australia, New Zealand), Asia (China, Vietnam, Malaysia, Indonesia, Thailand, the Philippines), Europe (France), and North America (USA).

Not all desired criteria could be uniformly met; further details are provided in the online Annexure[1].

8.3 CASE STUDIES BY FAMILY OF APPLICATION OF THE TEEBAGRIFOOD EVALUATION FRAMEWORK

Each example from the five families of application is presented with a brief introduction, key objectives, approaches and methods used and key results. The biophysical and/or monetary information in each case study is shown using the TEEBAgriFood Evaluation Framework (detailed in Chapter 6). Recommendations for further research and potential policy questions along with lessons learned in applying the evaluation framework end each of the ten case studies.

Table 8.3 Selection criteria for case studies

	Scope	Criteria
1	Primary scope	Does the example provide a holistic assessment of agriculture or food system? (not just production or consumption, but including the positive and negative externalities connected with these)
		Does it address at least one of the five groups of applications of TEEBAgriFood Framework (please indicate the group)? Comparisons of: • Management/production systems (i.e., organic versus conventional) • Products (i.e., grass-fed beef versus beef from feedlots) • Diets (i.e. Mediterranean diet versus fast-food diet) • Policy scenario (i.e. soda tax, results before and after application) • National accounts (i.e. taking stock of environmental goods and services from agriculture versus conventional accounts)
		Is it documented in a peer-reviewed article or a well-respected source of grey literature? (provide reference or link and contact information)
2	Level of assessment	Does it address at least one of aspect of the food value chain: For example, production, processing & distribution or consumption?
		Does it compare at least two contrasting systems?
		Does it focus on the level of whole systems or individual practices?

Table 8.4 In-depth selection criteria

1	Thematic scope	Does the example include produced, natural, social, and/or human capital?
		Does it include monetary values, biophysical and/or social indicators?
2	Method used	Is the evaluation method used in the assessment quantitative or qualitative?
		Are economic or bio-physical models used?
		Quantitative: correlation, econometric models, biophysical models, simulation, cost-benefit analysis, cost-effectiveness analysis, etc.
		Qualitative: evaluating choices against ethical and social decision principles and values (rights, justice and social equity, poverty reduction, human health, ecological, and cultural values, etc.).
		Integrated approaches and methods: Life Cycle Analysis, cost benefit analysis, multi-criteria analysis etc.
3	Scale of assessment	What is the scale of assessment (local, national, regional, global)?
4	Geographic scope	Does this apply globally or to a specific region/country?
5	Perspectives on sustainability	At what level (e.g. farm, business, society) does the application propose a sustainable alternative? To what extent are different forms of capital addressed; for example, is social and human capital included in the analysis?

8.3.1 Agricultural management systems

Two examples are presented in this section: i) agro-ecological versus conventional rice management practices, and ii) organic versus conventional agriculture.

CASE STUDY 1: Rice management practices: agro-ecological versus conventional

Rice is central to the food security of half the world (FAO 2014). Rice production provides a range of ecosystem services beyond food production alone. For example, rice systems support cultural values in many regions of the world, can provide important habitat for wildlife, and are capable of sustaining natural pest control and their inherent fertility, under certain management systems (Settle *et al.* 1996; Halwart and Gupta 2004). At the same time, rice production has been linked to a range of adverse environmental impacts such as greenhouse gas (GHG) emissions, air and water pollution as well as freshwater consumption.

The question of interest is how to reduce trade-offs and enhance synergies between generating positive externalities (rice production, cultural benefits) and minimizing negative ones (such as water use levels and pollution), such that the well-being of farmers, and society at large is enhanced.

The TEEBAgriFood rice study (Bogdanski *et al.* 2016) set out to identify those farm management practices that offer the best options to reach synergies, and reduce trade-offs between different management objectives in rice agro-ecosystems in five case study countries around the globe: the Philippines, Cambodia, Senegal, Costa Rica and the United States (California). The analysis refers to rice production, on the one hand, and a range of different externalities, i.e., an environmental impact or ecosystem service, on the other, to show potential trade-offs or synergies between the two.

A scenario analysis was carried out to show the effect of different management objectives. For example, if Senegal was to change all its irrigated lowland rice systems from conventional management to water-saving rice production systems, society would save about US$ 11 million in water-related health and environmental costs, while at the same time increasing yields and farm incomes. Alternative, ecological pest management and the importance of cultural ecosystem services provided by rice systems is also highlighted in the study, although not quantified or included in scenarios. The results have confirmed the need for practice and location specific typologies to show the full range of external benefits and costs.

In a broad sense, this case study shows that by assessing farming systems as a whole, taking negative and positive externalities into focus along with standard production metrics, it is possible to highlight key synergies and trade-offs. Often where trade-offs are expected in rice production systems, alternative management practices may result in win-win outcomes.

Table 8.5 indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework. The agricultural output in terms of rice production, income and purchased inputs was captured in the study at farm-level in the agricultural production side of the value chain. Other provisioning services (for example, energy generation from rice husks) were monetized using direct market valuation. Regulating services (nutrient cycling, pest control, genetic diversity etc.) or supporting services (such as habitat provisioning) were also assessed where data was available. Cultural ecosystem services such as heritage, tourism, access to traditional rice varieties were also captured in the study. The study also describes (but does not measure) impacts on human health due to pesticide exposure, and impacts on ground water and air. These are reflected in the changes in human and natural capitals, respectively by using cost benefit analysis.

Policy questions that a TEEBAgriFood Framework-testing study can inform

Given the critical importance of rice to food security around the world, governments often have many policies developed to support the consistent, low-cost supply of rice to consumers. In many cases, these involve government-setting of rice commodity prices, and subsidies for inexpensive inputs—in particular—pesticides. If all externalities were to be included in prices, this would be turned around, as pesticides would become much more expensive (see for example, case study 7 (pesticide tax), and Praneetvatakul *et al.* (2013)). The challenges for policy makers include:

- In determining rice policy, all the benefits and costs of different rice production systems should be taken into consideration (including water and nutrient flows, health impacts, cultural values and greenhouse gas emissions).
- As research has shown, inexpensive prices for agricultural chemicals lead to intensive use in rice, which then leads to pest resistance and the need for even more inputs. Policy on prices of pesticides should be designed to reflect these negative externalities and encourage alternative modes of pest control.

Table 8.5 Case study 1 (rice): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	**Agricultural production**	**Manufacturing and processing**	**Distribution, marketing and retail**	**Household consumption**
Outcomes (change in capital)				
Natural capital	🟩 Impact on groundwater and surface water quantity and quality	▨	▨	▨
Produced capital	▨	▨	▨	▨
Human capital	🟩 In disability adjusted life years (DALYs), Health costs related to pesticide use, Moderation of extreme events	▨	▨	🟩 Dietary variability
Social capital	▨	▨	▨	▨
Flows				
Outputs				
Agricultural and food production	🟦 Rice yield	▨	▨	▨
Income / operating surplus	🟦 Income	▨	▨	▨
Purchased inputs to production				
Labour	🟦 Wages	▨	▨	▨
Intermediate inputs (fuel, fertilizer, etc.)	🟦 Fertilizers, fuel	▨	▨	▨
Ecosystem services				
Provisioning	🟦 Habitat provisions, energy from husk	▨	▨	▨
Regulating	🟧 Watershed management, Freshwater saving, Nutrient cycling, Soil fertility enhancement, Pest control, Groundwater recharge, Genetic diversity	▨	▨	▨
Cultural	🟩 Cultural Heritage, Maintenance of rice terraces, Tourism, Traditional rituals and spiritual experiences related to rice system, Traditional knowledge on rice cultivation	▨	▨	🟩 Access to and consumption of traditional rice varieties
Residual flows				
Food waste	▨	▨	▨	▨
Pollution and emissions (excess N & P, GHG emissions, etc.)	🟦 Water pollution from pesticides, Water pollution from fertilizer	▨	▨	▨
	🟩 Eutrophication			

🟩	Descriptive information available
🟧	Quantitative information available
🟦	Monetized information available
▨	Not included in study

As this study suggests, there are many potential "savings" that can be applied to conventional rice production systems, for example in improved water and nutrient management, in reduced use of agricultural inputs, in the potential for integrating fish in rice paddies when pesticides are not present. Such savings could permit greater support for farmer training and sharing on ecological approaches to rice production, such that the cost of rice does not need to increase in order to produce the same or higher yields more ecologically.

Lessons learned

The focus of this study was specific practices in rice production in five countries (Bogdanski *et al.* 2016). Practices of course are very numerous and their collective impacts on ecosystem services are nuanced and complex. Yet for decision-makers to use a TEEB-like analysis to understand in what ways a rice production system can generate positive externalities and minimize the negative, a way of synthesizing these impacts and providing a trade-off analysis is needed. Equally, such a synthesis would bring the opportunities for synergies to the attention of decision makers and point out where trade-offs can be minimized and yields can be maintained while ecosystem services are being generated and enhanced. The framework does not, as yet, have capacity to point to these areas of trade-offs and synergies, that may be of great interest to decision-makers. In the literature for the rice feeder study, there is a lack of monetary valuation methodologies of agro-ecosystem benefits. A strength of the framework is that it goes beyond quantitative and monetary measures and gives room to qualitative discussion as well. However, to do trade-off analysis accurately will require data and studies that provide a comprehensive data set that goes beyond food production alone (as is typically done in agronomic studies). Often studies comparing yield and other ecosystem services are missing. This also counts for environmental studies that might omit agronomic values. In addition, environmental and socio-economic benefits and costs are often studied in isolation from each other, despite them being closely interconnected.

CASE STUDY 2: Organic versus conventional agriculture

A comparison of organic and conventional agricultural systems at field, region and global scale is presented here. In this study, 12 different ecosystem services associated with both systems in New Zealand agriculture are explored, including 'provisioning services' – i.e. food and other raw materials – as well as intangible, non-marketed 'regulating', 'cultural' and 'supporting' services (Sandhu *et al.* 2015). The study also estimates the economic value of these ecosystem services for both organic and conventional systems based on experimental assessment and direct market valuation using market prices and avoided cost method.

The total economic value of ecosystem services in organic fields ranged from US $1610 to US $19,420 ha− 1yr− 1 and that of conventional fields from US $1270 to US $14,570 ha− 1 yr− 1 (Sandhu *et al.* 2008). All ecosystem services including food production values were higher in organic fields as compared to the conventional ones. This is due to the higher market price for organic produce, and comparable yields in both systems. Regulating and supporting services were found to be higher in organic than the conventional agriculture (pollination, biological control, nutrient cycling etc.). Two ecosystem services out of 12 investigated (biological control of pests and mineralization of plant nutrients) were then extrapolated to 110 countries in 15 global regions to illustrate the potential magnitudes for farming in those regions (Sandhu 2015). This approach can help improve understanding of the potential contribution of non-marketed ecosystem services to global agriculture. It does not advocate large-scale conversion to organic practices. However, if only 10 per cent of the global arable land utilised such ecosystem services-enhancing techniques, then this study shows that the total value of ecosystem services can surpass the total cost of inputs (Sandhu 2015). However, this study did not consider regional climatic conditions, social-political factors, crop management changes and their market prices, or the rate of uptake of organic farming practices by farmers while extrapolating the results (Sandhu 2015).

Table 8.6 indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework. This study identifies trade-offs between two alternative production systems by comparing ecosystem services that include provisioning, regulating and cultural services. Organic agriculture depends on enhanced above and below ground biodiversity, which provides pollination services, biological control of pests and diseases, nutrient cycling etc. It can take time for such processes to reach optimum levels; therefore, there could be some trade-offs in the level of production and profitability in the interim. The study quantified various ecosystem services and provided monetary estimates in two production systems using direct market valuation and an avoided cost approach (**Table 8.6**). It captured visible and invisible flows in terms of 12 ecosystem services at the production side only. However, it did not quantify changes in natural, physical, social and human capital. The impact of different management systems on land, as a form of natural capital is described.

Table 8.6 Case study 2 (organic/conventional agriculture): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	**Agricultural production**		**Manufacturing and processing**	**Distribution, marketing and retail**	**Household consumption**
	Organic	**Conventional**			
Outcomes (change in capital)					
Natural capital	Land improvement, biodiversity structure	Land degradation			
Produced capital					
Human capital					
Social capital					
Flows					
Outputs					
Agricultural and food production	Grains yield	Grains yield			
Income / operating surplus	Profits	Profits			
Purchased inputs to production					
Labour	Wages	Wages			
Intermediate inputs (fuel, fertilizer, etc.)	Fuel, irrigation etc.	Fuel, irrigation, fertilizer, pesticide use			
Ecosystem services					
Provisioning	Raw material, bioenergy	Raw material			
Regulating	Soil formation, Nitrogen fixation, Pollination, Biological control of pests, Mineralization of plant nutrients, Soil fertility, Hydrological flow, Shelterbelts	Soil formation, Nitrogen fixation, Pollination, Biological control of pests, Mineralization of plant nutrients, Soil fertility, Hydrological flow, Shelterbelts			
Cultural	Land improvement, biodiversity structure	Aesthetics			
Residual flows					
Food waste					
Pollution and emissions (excess N & P, GHG emissions, etc.)					

Higher value	Lower value	
🟩	🟩	Descriptive information available
🟧	🟨	Quantitative information available
🟦	🟦	Monetized information available
⬜	⬜	Not included in study

Policy questions that a TEEBAgriFood Framework-testing study can inform

The following policy questions address the need to increase food production without impacting human and environmental health.

- Given the significant value of some non-marketed ecosystem services, especially in organic production systems, how can markets be built to recognise these values, and the contribution of farmers in providing them?
- Recognizing the large international trade in conventional agricultural inputs, is it possible to build alternative markets for ecosystem services that sustain production, and at what scale (i.e. in one state, global or regional)?
- The market share of organic products continues to increase, but supply often lags demand. What policies can be put in place to optimize the supply-demand equation for organic foods?
- What would be the health benefits to farmers, farm workers and consumers of policies promoting greater reliance on ecosystem services in production over conventional inputs? (See case study 7 on pesticide taxes in Thailand, for some indication.)

Lessons learned

Monetary valuation of ecosystem services can help to draw attention to the ecosystem services that are neither valued nor recognized in farmer income. The current TEEBAgriFood Framework does quite adequately address the positive externalities of different agricultural systems, although the scope for providing comparisons needs to be further developed. In further elaborations of this type of study (and for the Framework), it would be valuable to reflect on time dimensions in the comparisons. Ecosystem services in organic agriculture may require longer than one season to provide full levels of service (biological control, for example, or the building of soil fertility through cover crops), and yet can be reduced through one season of pesticide application or misuse of fertilizers. The Framework may serve to encourage more research on other aspects (such as nutrition, health and social equity) not yet covered, even within the production sectors.

8.3.2 Business analysis

Two examples are presented in this section: i) grass-fed versus grain-fed beef, and ii) palm oil.

CASE STUDY 3: Grass-fed versus grain-fed beef

Current conventional systems produce tremendous quantities of meat at relatively affordable prices, yet many key questions about this practice arise through a TEEB-like assessment. In this case study we have drawn from multiple sources to draw the outlines of the visible and invisible flows in two contrasting beef production systems: grain-fed and grass-fed beef in the United States. Many issues related to the beef industry are well known, so we highlight only one from each food system stage that are less known, and then focus on possible policy considerations (more details can be found in the online Annexure).

Production (and associated waste); Pollution impacts: Animals produce significant amounts of greenhouse gases such as methane and carbon dioxide during digestion. By some estimates, when emissions from land use and land-use change are included in the calculation, the livestock sector accounts for 18 per cent of CO2 deriving from human-related activities (Steinfeld *et al.* 2006). Producing 1kg of cheap beef generates as much CO2 as driving 250km in an average European car or using a 100W bulb continuously for 20 days. Animal agriculture is also responsible for roughly 37 per cent of all human-induced methane emissions, which has a global warming potential 23 times that of carbon dioxide (Steinfeld *et al.* 2006). The relative difference in enteric fermentation (where methane is produced in the rumen as a digestion process) and manure emission levels per head between grain-fed and grass-fed beef is not well understood. However, there are important production differences, and areas requiring careful contextualization.

Grain-fed beef production: It has been suggested that fertilizer use to support animal agriculture will generate nearly twice as much N_2O as would its use for crops destined for direct human consumption. This is thought because "N_2O is first produced when the fertilizer is applied to the cropland for growing the animal feed grain and then is produced a second time when the manure-N, which has been re-concentrated by livestock consuming the feed, is recycled onto the soil or otherwise treated or disposed of" (Davidson 2009).

Grass-fed beef production: If well-managed and promoted by use of increased permanent cover of forage crops, pastured livestock can reduce soil erosion and emissions while sequestering carbon in pasture soils (Teague *et al.* 2016). However, grass-fed cattle in the Midwestern United States must be fed hay in the winter months when pastures are under snow.

Table 8.7 Case study 3 (grass vs. grain-fed beef): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	Agricultural production		Manufacturing and processing	Distribution, marketing and retail	Household consumption	
Outcomes (change in capital)						
Natural capital	Land degradation, water pollution		Air and Water pollution			
Produced capital						
Human capital					Grain-fed beef: Increased likelihood of rapid evolution and proliferation of antibiotic-resistant strains of bacteria.	Grass fed beef: lower in calories, healthier omega-3 fats, more precursors for vitamins A and E, higher levels of antioxidants, 7 x beta-carotene
Social capital					Grain-fed beef: Social fabric of communities undergoes significant change as industrialized farm animal operations replace family farms	
Flows						
Outputs						
Agricultural and food production	Grain-fed beef: substantial contribution to US national economy, production	Grass-fed beef: small but growing portion of national beef production	Grain-fed beef: Vertical integrators in meat processing business Grass-fed beef: largely locally owned services; these generates seven times that value to the local community			
Income / operating surplus						
Purchased inputs to production						
Labour						
Intermediate inputs (fuel, fertilizer, etc.)						

Ecosystem services				
Provisioning	Grain-fed beef: highly productive but inherently inefficient, benefiting from subsidies to corn and soy.	Grass-fed beef: variable but often higher costs of production		no clear-cut, consistent taste differences between grain-fed and grass-fed beef
Regulating	Grain-fed beef: Excessive nutrient loading, water contamination from CAFOSs known to cause simplification of ecosystems and services	Grass-fed beef: well managed grazing may support soil organisms and grassland diversity		
Cultural	Interest and pride in grass-fed ranching culture is strong			Consumers have been shown willing to pay higher prices for grass-fed beef
Residual flows				
Food waste				
Pollution and emissions (excess N & P, GHG emissions, etc.)	Grain fed beef: Animal waste from CAFOs not uniformly treated; often applied to cropland in ways that are detrimental to soil health and water nutrient loads.		Grass-fed beef: Careless management of grazing land can contribute to ecosystem degradation, while holistic management can contribute to healthy grasslands	

🟩 Descriptive information available
🟧 Quantitative information available
🟦 Monetized information available
⬜ Not included in study

Both the production and transportation of beef have costs and greenhouse gas implications. In addition, managed pastures may require intensive inputs of fertilizers and other amendments. Industrial agriculture will always perform better when looking at quantity of beef produced per land area than more agroecological approaches. Yet, what causes global warming is the total net emission of greenhouse gases per area, regardless of yields. Grain-fed livestock's overall contribution to greenhouse gases is substantial, and intensive meat production has vastly increased in the last few decades (Carolan 2011). Efficiencies in production will not offset increases in total emissions, if livestock production continues to expand in the same way it has through industrial animal feedlot operations.

Processing and distribution (and associated waste); Value capture: There are distinct economic disparities between farm communities that include industrial farm animal production units and those that retain locally owned farms where animals are finished on-farm (Pew Charitable Trusts and Johns Hopkins Bloomberg School of Public Health 2008). This study used direct market valuation to estimate the impact of local farms on the community. It has been estimated that every dollar earned on a locally-owned farm generates seven times that value to the local community. In contrast, industrial farm animal facilities have a much lower multiplier effect because their purchases of feed, supplies, and services tend to leave the community, going to suppliers and service providers mandated by the vertical integrators in the meat processing business (ibid.).

Consumption (and associated waste); Health Impacts (Nutrition, Lifestyle diseases, Antibiotic resistance, etc.): As noted above, an infectious agent that originates at an industrial farm animal facility may persist through meat processing and contaminate consumer food products in homes or restaurants, resulting in potentially serious disease outbreaks far from the facility (Pew Charitable Trusts and Johns Hopkins Bloomberg School of Public Health 2008). Proliferation of antibiotic resistant bacteria is a major health concern.

Animal sewage from industrial farm animal facilities is generally stored in lagoons intended to reduce pathogenic elements, but even the best managed are estimated to kill off only 85 to 90 per cent of viruses, and 45 to 50 per cent of bacteria (Carolan 2011).

The available evidence comparing grass-fed versus grain-fed beef production brought together in this case study, from a multitude of recent reports, highlights the need to integrate often diverse data to carry out a TEEB analysis (**Table 8.7**). The lack of common metrics makes analysis difficult; production values are economically based, whereas production and consumption impacts are based on health metrics (few of these, as yet, have been quantified). Synthesizing the resulting synergies and trade-offs and integrating the results remains challenging.

Policy questions that a TEEBAgriFood Framework-testing study can inform

The global food system is geared towards enabling high levels of consumption of cheap meat. A few key potential policy changes include:

- Taking stock and assigning value to all the negative and positive externalities of beef production systems, including health concerns over antibiotic resistance, worker safety, animal welfare, impacts on local and often low-income communities, and healthy diets, to begin. It may be impossible make policy decisions that promote specific outcomes on any one of these concerns without having impacts on others--this helps further highlight the need for an underlying systems model for which the impacts of different policy interventions could be played out. A holistic model of the farming systems should be able to indicate not just the costs, but also the benefits of the contrasting production systems. For example, a complete assessment of the implication of single policy measures, such as banning antibiotic use in beef production, or removing subsidies for animal feedstocks would give policy makers the ability to perceive "ripple effects" on other parts of the food system.

- Supporting more sustainably produced beef through mid-sized diversified farming systems; building support for transitions to diets and food systems that incorporate smaller quantities of higher quality meat consumption.

- Probing where, along the food system, policy measures can be most effectively applied. For example, Bittman (2011) notes a history and precedence in the United States where revenues for farm support measures were raised on taxes on food processors. If indeed it is the "food giants" of food processors (conceivably including concentrated animal feeding operations, or CAFOs) that have profited mightily from subsidized corn and soy, thus they might be asked to share more the cost of negative externalities.

Lessons learned

While many aspects of beef production fit well into the TEEBAgriFood framework, it is not clear where to place some others that may be more global or "underlying". This is a larger challenge within the TEEBAgriFood framework, as it remains difficult to differentiate between "visible and invisible flows" when examining contrasting examples. The overall impact of meat production on global food security is an example of this. Collectively, cattle, pigs and poultry consume roughly half the world's wheat, 90 per cent of the world's corn, 93 per cent of the world's soybeans, and close to all the world's barley not used for brewing and distilling (Tudge 2010). The discourse on how to address the challenges of feeding a growing world population often focuses on a perceived imperative to simply increase production; yet simple production of calories is not the fundamental issue, as world agricultural production of calories is more than sufficient to feed each person more calories than are needed per day. The extent of croplands devoted to producing grain and soy-based animal feed is estimated at about 350 million hectares; in the United States an estimated 50% of all grain produced goes to animal feed. Using productive croplands to produce animal feed imposes a negative force on the world's potential food supply (Foley *et al.* 2011). The conversion of tropical rain forests in Latin America to produce soy feed for animal agriculture, much of it in other continents including the USA, is equally an issue of social values in conflict. Multi-criteria analysis method could be used in such studies to provide policy relevant advice to the meat industry, where several bio-physical (GHG emissions, impacts on land use, water use etc.) and social (consumer perceptions, public health etc.) criteria exist.

CASE STUDY 4: Palm oil

Raynaud *et al.* (2016) quantify and monetize the key natural capital impacts of palm oil across the 11 leading producer countries, with a focus on Indonesia, the world's largest palm oil producer. The study quantifies human capital impacts and also captures visible and invisible natural capital costs linked to the growing, milling and refining stages of palm oil production. It does not include transportation, food processing and consumption.

Palm oil production in the 11 countries assessed has a natural capital (e.g. land degradation, loss of biodiversity, air and water pollution) cost of $43 billion per year compared to the commodity's annual value of $50 billion. Producing one tonne of crude palm oil (CPO) has a natural capital cost of $790 while one tonne of palm kernel oil costs $897. The results also show that underpayment and occupational health impacts have a total human capital cost of $592 per full-time employee, or $34 per tonne of palm oil and $53 per tonne of palm kernel oil.

Table 8.8 indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework. This study covered some elements at the production and processing side of the Framework as demonstrated by **Table 8.8** It captured visible and invisible flows in terms of ecosystem services at the production side only using avoided cost and damage cost methods. It captured changes in stocks of produced, natural and human capital and provided information of the health impacts. A complete analysis using the Framework could help steer policy concerning the clearing of tropical forest, international trade with largest consumer of palm oil (e.g. India) and the subsequent health issues from palm oil consumption in India.

Policy questions that a TEEBAgriFood Framework-testing study can inform

Given increasing demand of palm oil, an application of the TEEBAgriFood Evaluation Framework suggests following questions that can be addressed at policy level.

- How can markets be built to recognise the value of natural, social and human capital, and the contribution of small holders in providing them?
- How can policy help to internalize negative externalities of the palm oil production sector to minimize losses of natural and human capital?
- Recognising the global trade in palm oil, is it possible to map all externalities and be able to identify the stakeholders who should pay for these (or be compensated for external benefits provided)?
- What policies can be put in place to manage supply-demand of palm oil production?

Lessons learned

The palm oil study focused largely on production and distribution and evaluated impacts on natural capital and human health. Various social and natural components were not explored, including ecosystem services (soil erosion control, biodiversity, water regulation, other agricultural production that support subsistence livelihood, etc.). The TEEBAgriFood Framework can help illuminate more of the costs and benefits associated with distribution, help inform policy options such as impacts of land clearing on the local and global environment and help assess health impacts in countries that are largest consumers of palm oil.

Table 8.8 Case study 4 (palm oil): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	Agricultural production	Manufacturing and processing	Distribution, marketing and retail	Household consumption
Outcomes (change in capital)				
Natural capital	🟦 Land degradation, loss of biodiversity	🟦 Air and water pollution, loss of biodiversity		⬜
Produced capital	⬜	⬜		⬜
Human capital	🟩 Health impacts of fuel use, fertilizer application, and pesticide application, Health impacts from air pollution from forest/ biomass burning, Occupational health	🟩 Health impacts due to GHG emissions in processing		🟦 Health impacts in consumers
Social capital	⬜	⬜		⬜
Flows				
Outputs				
Agricultural and food production	🟦 Fruit yield	🟦 Oil production		⬜
Income / operating surplus	🟦 Income from yield	🟦 Income from Palm Kernel Oil, Income from Crude Palm Oil		⬜
Purchased inputs to production				
Labour	🟦 Wages of casual and permanent workers	⬜		⬜
Intermediate inputs (fuel, fertilizer, etc.)	🟦 Cost of fertilizer, pesticide etc.	⬜		⬜
Ecosystem services				
Provisioning	🟦 Other crops such as rice for home consumption, cattle etc.	🟦 Methane capture from Palm Oil Mill Effluent for energy		⬜
Regulating	🟦 Soil erosion, Water quality impacts of sedimentation, Water quality impacts of sedimentation, Land conversion and loss of biodiversity, including endangered species	⬜		⬜
Cultural	🟩 Land dispossession and potential displacement of communities, Workers' rights violations, Loss of livelihood alternatives	⬜		⬜
Residual flows				
Food waste	⬜	⬜		⬜
Pollution and emissions (excess N & P, GHG emissions, etc.)	🟦 Terrestrial, marine, and freshwater ecosystem toxicity of pesticides and fertilizers, GHG emissions from fertilizer production, pesticides and other raw materials, Change in C stocks due to deforestation	🟦 GHG emissions from Palm Oil mill effluent		⬜

🟩	Descriptive information available
🟧	Quantitative information available
🟦	Monetized information available
⬜	Not included in study

8.3.3 Dietary comparison

Two examples are presented in this section: i) diets in France and, ii) ten diet scenarios and carrying capacity of agricultural land in US.

CASE STUDY 5: Welfare and sustainability effects of diets in France

The chosen study assessed French dietary recommendations in light of multiple sustainability dimensions such as taste, cost, welfare effect, deaths avoided, GHG emissions and acidification (Irz 2016).

A model of rational behaviour is developed by Irz (2016), building on microeconomic theory of the consumer under rationing (dietary constraints), with the goal of identifying diets compatible with both dietary recommendations and consumer preferences. Six different sustainable diet recommendations based on consumer guidelines in France are considered in this study. The dietary recommendations assessed are small adaptations of the current French diet, a 5% relative variation in the level of constraint of its baseline level. The constraints derive from nutrient based (salt intake, saturated fat acids, (SFA)) and food-based (fruit and vegetables, meat), health (added sugar) and environmental (CO_2 emissions) that estimates the effects in terms of chronic disease prevalence and mortality was applied. The effect on environmental indicators was estimated as well, making use of a Life Cycle Analysis (LCA) approach. These estimates take into account each stage of the production, transformation, packaging, distribution, use, and end-of-life of products.

The percentage change in consumption of the 22 food groups was calculated for each of the different restrictions. Due to the complementarity and substitutability among the food products captured in the model, a decrease in meat consumption of 8 grams/day (-5%) results in relatively important changes in consumption of starchy foods (-2.2%) and dairy products (+3.4%). Also, within subgroups substitutions occur, for example more fish (+7.5%) and less eggs (-3.3%). The restriction on only red meat results in smaller adjustments in food consumption.

The overall benefits and cost-effectiveness of the recommendations were calculated, taking into account economic, health and environmental elements. The result emerged that most restrictions are very cost-ineffective. The next step is a more complete cost-benefit analysis, in which the benefits and costs of the measures can be considered jointly. Valuing the positive effects with the social cost of carbon (32 Euro/ton), the value of an avoided death (240,000 Euro), justifies spending considerable amounts to promote the recommendations targeting Fruits & Vegetables (F&V), Salt, Saturated Fatty Acids (SFA), added-sugar and red meat. With higher social cost for carbon (185 Euro/ton) and a value for an avoided death closer to the value of a statistical life (1 million Euro), the benefits of targeting GHGs and consumption of all meat appear to be cost-effective as well. This way of reasoning makes it possible to rank the recommendations to be promoted.

The model developed in this study weighs the taste cost (or short-term welfare costs) incurred by consumers against the health and environmental benefits induced by their adoption. Based on the complete cost-benefit analysis the authors conclude that: i) measures focused on intakes of F&V, SFA, sodium, and to some extent, added-sugar, provided that they lead to at least a 5% change in the consumption of the targeted food or nutrients, would be a valuable investment; ii) informational measures to promote a reduction of red meat or all meat consumption would be valuable investment only for relatively high values of CO_2. A last conclusion: the values of health benefits induced by dietary recommendations are often much greater than those of environmental benefits (except in the case of a very high CO_2 price).

Table 8.9 indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework. Various elements are covered for the consumption side of the value chain in this study. Outcomes for human capital are also described and captured in monetary terms.

Table 8.9 Case study 5 (diets in France): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	Agricultural production	Manufacturing and processing	Distribution, marketing and retail	Household consumption
Outcomes (change in capital)				
Natural capital				
Produced capital				
Human capital				Value of avoided deaths (and VOSL)
Social capital				
Flows				
Outputs				
Agricultural and food production				
Income / operating surplus				Consumer costs
Purchased inputs to production				
Labour				
Intermediate inputs (fuel, fertilizer, etc.)				
Ecosystem services				
Provisioning				
Regulating	Environmental costs			
Cultural				Different income-groups separated
Residual flows				
Food waste				
Pollution and emissions (excess N & P, GHG emissions, etc.)				Value of carbon

🟩	Descriptive information available
🟨	Quantitative information available
🟦	Monetized information available
⬜	Not included in study

Policy questions that a TEEBAgriFood Framework-testing study can inform

This study provides policy makers with a framework for analysing the societal impacts of relatively small changes in dietary patterns, on economic, health and environmental dimensions. It could equally be used to ask:

- What would be the impacts of larger changes (greater than 5 per cent) on these dimensions? Is the existing model able to reliably estimate the impact of such (larger) changes?
- While the study finds that taxes on health-based restrictions are not likely to be cost-effective, it also finds that the values of health benefits induced by dietary recommendations are often much greater than those of environmental benefits; if taxes are not effective, what alternative policy measures could capture and attribute the costs of different diet choices?

Lessons learned

The comparison of diets as presented in the study provides a methodology for assigning the costs and benefits of different impacts jointly. Information from different scientific disciplines is required, even as different effect models must be used and many assumptions have to be made. By using monetary valuation estimates, the value of the different effects can be assessed jointly. From a societal perspective, the joint analysis is preferable. What is interesting for TEEBAgriFood as well is that the values of health benefits induced by dietary recommendations are often much greater than environmental benefits (except in the case of a very high CO_2 price).

CASE STUDY 6: Ten diet scenarios and carrying capacity of agricultural land in US

This study analyses impacts of dietary change on land use and carrying capacity by exploring 10 different diet scenarios (Peters *et al.* 2016). It uses a “Foodprint model” to estimate land requirements for 10 distinct diet scenarios:

- BAS (baseline)
- POS (positive control, intake of fats and sweeteners is reduced to make diet energy-balanced.)
- OMNI 100 (100 per cent healthy omnivorous)
- OMNI 80 (80 per cent healthy omnivorous)
- OMNI 60 (60 per cent healthy omnivorous)
- OMNI 40 (40 per cent healthy omnivorous)
- OMNI 20 (20 per cent healthy omnivorous)
- OVO (ovolacto vegetarian)
- LAC (lacto vegetarian)
- VEG (vegan)].

The reference diet (BAS) reflects contemporary food consumption patterns based on loss-adjusted food availability data from 2006–2008 (USDA Economic Research Service 2010). The concept of a “foodprint” is an analytical device related to assessing the capacity of a “foodshed”, defined as the geographic location that produces the food for a particular population.

The scenarios in this study used biophysical models pertaining to land use change explored how assumptions about the suitability of cropland for cultivated crops influences estimates of carrying capacity. The baseline scenario had the highest total land use requirement, 1.08 ha person^{-1} year^{-1}, followed closely by the positive control, 1.03 ha person^{-1} year^{-1}. Land requirements decreased steadily across the five healthy omnivorous diets, from 0.93 to 0.25 ha person^{-1} year^{-1}, and the total land requirements for the three vegetarian diets were all similarly low, 0.13 to 0.14 ha person^{-1} year^{-1}.

All dietary changes increased estimated carrying capacity relative to the baseline. Diet composition greatly influences overall land footprint.

Table 8.10 indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework. Agricultural output is quantified with other provisioning and regulating services. The impacts of change in diets on human capital (through health) are described as an outcome.

Table 8.10 Case study 6 (diets in US): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	**Agricultural production**	**Manufacturing and processing**	**Distribution, marketing and retail**	**Household consumption**
Outcomes (change in capital)				
Natural capital				
Produced capital				
Human capital				Nutritional security
Social capital				
Flows				
Outputs				
Agricultural and food production	Crop yields Livestock production	Energy Food wastage		Food products (vegetarian and meat based) Food wastage
Income / operating surplus				
Purchased inputs to production				
Labour				
Intermediate inputs (fuel, fertilizer, etc.)				
Ecosystem services				
Provisioning	Biomass			
Regulating	High impact on natural resources in grazing land, low impact in cropland			High food print in grazing land, low impacts in cropland
Cultural				
Residual flows				
Food waste				
Pollution and emissions (excess N & P, GHG emissions, etc.)	High GHG emissions in grazing land, Low GHG emissions in cropland			

🟩 Descriptive information available

🟧 Quantitative information available

🟦 Monetized information available

⬜ Not included in study

Policy questions that a TEEBAgriFood Framework-testing study can inform:

The scenarios focused solely on differences in food consumption patterns and resulting impacts on land use requirements, and thus the study lends itself to a specific set of policy questions such as:

- Given a limited, set amount of crop acreage and grazing land within a country, what dietary changes that can help attain different levels of food security?

- To what extent is each food commodity land requirement dependent on ecosystem services, and/or on external inputs? What are the relevant positive and negative externalities of the contrasting diets and associated food production systems?

- The concept of "foodsheds" is intended to describe a region where food flows from the area that it is produced to the place where it is consumed, including the land it grows on, the route it travels, the markets it passes through, and the tables it ends up on. Can such an analysis of "foodprints" contribute to understand 'foodsheds', and the theoretical land use requirements for building local food systems (thus also incorporating metrics on the positive and negative externalities of processing and distribution for local communities)?

Lessons learned

This case study provides per capita land requirements and potential carrying capacity of the land base of the continental U.S. under a diverse set of dietary scenarios. It provides a good example for the application to the consumption side of the TEEBAgriFood Framework. This study focused on land requirements for different types of diets and hence associated greenhouse gas emissions and food wastage. Such studies could also utilize economic valuation methods to examine the associated changes in the value of natural capital. Therefore, the TEEBAgriFood Framework can assist in addressing these issues, and help to inform policy.

8.3.4 Policy evaluation

Two examples are presented in this section: i) a pesticide tax in Thailand, and ii) the Sloping Land Conversion Program in China.

CASE STUDY 7: Pesticide tax in Thailand

Until the late 1990s policies in Thailand supported the use of pesticides, as in other lower income countries in East and Southeast Asia, in order to stimulate agricultural production. Subsidized farm credit programs and other causes led to the greater use of pesticides (Praneetvatakul *et al.* 2013). Over the period from 1987 to 2010 agricultural pesticide use in Thailand increased from 1 kg/ha to 6 kg/ha, on average, while the pesticide productivity (gross output per unit of pesticide use) decreased from 400 USD/kg to 100 USD/kg. Besides the negative effect of pesticides on the environment, the health of farmers, farm workers and consumers is also exposed to risks.

A study was undertaken by Praneetvatakul (2013) to provide a quantitative analysis of the external costs of pesticides, to help policy makers understand who was bearing these costs, and where policy might intervene to reduce or eliminate these. Two approaches were used.

In one approach, a set of base values for eight external costs (related to farm worker health, consumer health, and the environment) associated with the application of one kg of active pesticide ingredients was calculated, using the Pesticide Environmental Accounting (PEA) methodology (see partial equilibrium model in Chapter 7) developed by Leach and Mumford (2008). This analysis showed that by far the highest cost of pesticide externalities falls on farmer workers and their health (83 per cent) while health costs to consumers are estimated at 11%.

The second approach used data on government spending related to pesticide use, which was collected from government agencies as per Jungbluth (1996), to estimate the actual cost of pesticide use, looking specific policy measures such government budgets for pest outbreaks, pesticide research and enforcement of food safety standards.

Between these two analyses, the priority revealed by government spending shows that greater importance is placed on food safety, while considerably less resources are allocated to the protection of farm worker health. The impacts of a pesticide tax were considered but research from various countries shows that the demand for agricultural pesticides is typically inelastic and that a tax would have a weak effect on demand, though it would generate considerable government revenues (Falconer and Hodge 2000). The study authors estimate that an environmental tax would raise pesticide prices by 11-32 per cent, yet would be insufficient to address the problem (see Dose Response Function method in Chapter 7). Since the greatest costs are currently being incurred on the farm by pesticide appliers and pickers, it can be questioned if a pesticide tax will actually address these costs unless it is explicitly formulated to do so. To best target where interventions are needed, the study recommends the introduction of measures supporting non-chemical pest management methods, focusing on on-farm practices, such as Integrated Pest Management (IPM) methods, Farmer Field School (FFS), farmer training and education.

Table 8.11 indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework, demonstrating how policy makers might use such studies to make external costs visible, and thus help to define economic policies (e.g. taxes or incentives) for pesticide use. To be effective, policies and social institutions must address areas of greatest costs and benefits along the food system; the TEEBAgriFood Framework has utility in identifying these areas. This study included the food value chain from impacts of production methods to impacts on consumer health. It referred to ways that ecosystem services (non-chemical pest control) could mitigate costs on the environment, and human health.

Table 8.11 Case study 7 (pesticide tax): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	Agricultural production	Manufacturing and processing	Distribution, marketing and retail	Household consumption
Outcomes (change in capital)				
Natural capital				
Produced capital				
Human capital	Farm worker health impact by applying pesticides, Farm worker health impact – effects from picking, Health costs due to acute pesticide poisoning, Costs related to BPH outbreak in 2010			Consumer health – groundwater, Pesticide contamination of fruit and vegetables
Social capital				
Flows				
Outputs				
Agricultural and food production	Gross output			
Income / operating surplus				
Purchased inputs to production				
Labour				
Intermediate inputs (fuel, fertilizer, etc.)				
Ecosystem services				
Provisioning				
Regulating	Habitat for biodiversity, Beneficial insects for pest control			
Cultural				
Residual flows				
Food waste				
Pollution and emissions (excess N & P, GHG emissions, etc.)	Pesticide impact on aquatic life, birds, bees, insects			

🟩	Descriptive information available
🟧	Quantitative information available
🟦	Monetized information available
⬜	Not included in study

Policy questions that a TEEBAgriFood Framework-testing study can inform

This study provides an opportunity for policy makers to assess the following:

- Can the results aid policy makers in determining where interventions will provide the most benefits? If clear negative externalities can be quantified (as they have been in this study), yet experience in other countries indicate that a pesticide tax may not be sufficient to change outcomes, what other measures might accompany or replace tax measures?
- What would be the outcomes of incorporating impacts and benefits generated by ecosystem services in alternative pest management strategies? For example, what would be the impacts on pesticide policy if health impacts on farm workers were considered? Could consideration of the additional benefits possible for incorporating aquaculture in rice production systems (where pesticides are minimized or eliminated) change the equation between benefits and costs, and for whom?

Lessons learned

This case study suggests that there is a need for a change from an institutional framework that promotes pesticides to one that takes into account the risks and is adjusted to the true costs and benefits of their use. The TEEBAgriFood Framework takes these costs and benefits into account, showing the external costs of pesticide use on consumers' health, farmers' health and the environment on a country level. It appeared that the majority of the external costs of pesticide use accrue to farmworkers and not to consumers, yet the study is one of the few that records impacts across the food value chain. In addition, the results show that an environmental tax would raise pesticide prices by 11-32 per cent. Considering these results, the TEEBAgriFood Framework has the potential to show which stages in the value chain or which (visible or invisible) flows are most affected by the use of pesticides. The Framework can thereby help direct policy. Since analysis shows that the greatest costs are currently being incurred on the farm, amongst pesticide appliers and pickers, it can be questioned if a pesticide tax will actually address these costs. The study noted that pesticide demand is fairly inelastic and is not likely to decrease because of the tax. It is also unlikely that the tax will be applied in a manner that addresses farmworker health (or provides funding research for production methods that use less pesticides) unless it is explicitly formulated to do so. In order to reveal this potential, the relative impact of pesticide use in the different stages of value chains or between (visible or invisible) flows need to be made clear within the Framework, in order to provide policy guidance on where interventions should be developed.

CASE STUDY 8: The China Ecosystem Assessment: Sloping Land Conversion Program

The study showcased here reports on the results of the first Chinese Ecosystem Assessment (CEA), which covered all of mainland China from 2000 to 2010 (Ouyang *et al.* 2016). The CEA is the first assessment of various ecosystems and ecosystem services since the Sloping Land Conversion Program (SLCP) was started to stop deforestation and erosion that led to severe flooding along the Yangtze River in 1990s. Bio-physical assessment models such as hydrological models and the Integrated Valuation of Environmental Services and Trade Offs (InVEST) were used in the study to assess ecosystem services. All ecosystem services evaluated increased between 2000 and 2010, with the exception of habitat provision for biodiversity. Food production had the largest increase (38.5 per cent), followed by carbon sequestration (23.4 per cent), soil retention (12.9 per cent), flood mitigation (12.7 per cent), sandstorm prevention (6.1 per cent), and water retention (3.6 per cent), whereas habitat provision decreased slightly (–3.1 per cent).

Table 8.12 indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework. Various outputs in the form of agricultural products are quantified along with all ecosystem services (carbon sequestration, beneficial insects, soil retention etc.). The impacts on natural capital (changes in soil and water quality through soil and water retention) are also quantified in the study.

Table 8.12 Case study 8 (Chinese Ecosystem Assessment): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	Agricultural production	Manufacturing and processing	Distribution, marketing and retail	Household consumption
Outcomes (change in capital)				
Natural capital	🟧 Land degradation, water pollution	⬜	⬜	⬜
Produced capital	⬜	⬜	⬜	⬜
Human capital	⬜	⬜	⬜	⬜
Social capital	⬜	⬜	⬜	⬜
Flows				
Outputs				
Agricultural and food production	🟦 Food production, timber	⬜	⬜	⬜
Income / operating surplus	🟦 Output surplus	⬜	⬜	⬜
Purchased inputs to production				
Labour	🟦 Wages and Profits in watershed ecosystems conservation, Land rent	⬜	⬜	⬜
Intermediate inputs (fuel, fertilizer, etc.)	🟦 Fertilizer/pesticides inputs	⬜	⬜	⬜
Ecosystem services				
Provisioning	🟧 Food, timber	⬜	⬜	⬜
Regulating	🟧 Carbon sequestration, soil retention, sandstorm prevention, water retention, flood mitigation, Biodiversity conservation Habitat for biodiversity	⬜	⬜	⬜
Cultural	🟧 Agricultural heritage	⬜	⬜	⬜
Residual flows				
Food waste	⬜	⬜	⬜	⬜
Pollution and emissions (excess N & P, GHG emissions, etc.)	🟧 GHG emissions, surface runoff, leaching of chemicals	⬜	⬜	⬜

🟩	Descriptive information available
🟧	Quantitative information available
🟦	Monetized information available
⬜	Not included in study

Policy questions that a TEEBAgriFood Framework-testing study can inform

An important component of any food system transition will be the relative expansion and contraction of labour demands. This case study included in its focus, along with a number of ecosystem services, the wages and profits in watershed ecosystem conservation. The program has reduced poverty in the Yellow River basin by increasing the income of participating households through the compensation payment and shifting the labour force from farm activities to non-farm work. The study is also distinctive in being relatively long term, over ten years, and providing a contrast in the sense of "before" and "after" government intervention. Relevant questions include:

- Looking into the future, can the expansion in wages and labour be sustained?
- Will this require continued government interventions and subsidies?
- How can the value created through restoration of ecosystem services be applied to sustaining conservation and restoration activities over time?
- What are the linkages between protection of ecosystems, livelihoods and public health?

Lessons learned

Results from The Natural Forest Conservation Program (NFCP) and the Sloping Land Conversion Program (SLCP) are unique, thanks to the studies' size and longevity. The SLCP presents the results from a truly massive investment of more than US$50 billion, directly involving more than 120 million farmers in 32 million households. The Programs focused solely on production systems, but considered a wide range of ecosystem services that have large impacts on the landscape level of the production system (sandstorm protection, water retention, flood mitigation, etc.). It is interesting however that the study itself, while finding many positive benefits from the "payments for ecosystem services" schemes, nonetheless finds that many environmental challenges remain, including issues with water quality. This suggests several possibilities: that the interventions are not sufficiently targeting root causes, or that the incentive systems are not enough to overcome existing disincentives leading to environmental pollution. To inform policy, applying the TEEBAgriFood Framework could assist in addressing these policy questions, if the challenges are included in the scope of the study.

8.3.5 National accounts

Two examples are presented in this section: i) agriculture development in Senegal, and ii) Australian Environmental Economic Accounts in agriculture.

CASE STUDY 9: Agriculture development in Senegal

This study aims to provide analysis of the socio-economic and environmental impacts of the agriculture development through provision of World Bank's loan for 'sustainable and inclusive agribusiness development project' during 2014-2020 to the Government of Senegal (Millennium Institute 2015). The study examines scenarios for social, economic and environmental development based on alternative investment in small-scale ecological and knowledge-intensive approaches, as opposed to high external-input, agricultural systems, at a national level. The Millennium Institute used its Threshold-21 (T21) simulation model (system dynamics model)– an integrated and dynamic planning tool – that enables transparent cross-sectoral analyses of the impacts of policies, and enables exploration of their direct and indirect long-term consequences on social, economic and environmental development (Pedercini 2010).

Four scenarios are analysed in this study: the Base Run scenario (without the World Bank loan), the World Bank loan scenario (in which the World Bank loan is implemented as suggested, mainly focusing on investment in irrigation infrastructure), and two alternative scenarios in which the World Bank loan is implemented but its focus is changed towards the support of small producers and farmer training. In the base run scenario, crop production accounted on average for around 60 per cent of total agriculture GDP between 1980 and 1990, decreased to around 55 per cent between 2005 and 2015 and declines to less than 45 per cent between 2040 and 2050. In the same periods, value added from livestock increases from around 23 per cent to around 30 per cent to 44 per cent. Average life expectancy increases from less than 50 years in 1980 to around 60 years around 2010 and nearly 90 years at the end of the simulation in 2050. Water demand increases for most of the simulation period and stabilizes shortly after 2045.

In the World Bank loan scenario, crop value added is around 7 per cent higher than the base scenario. For the social indicators in 2050, agriculture employment is 27 per cent greater in the World Bank loan scenario than in the Base Run. The water stress index, the ratio between water demand and available water, in 2020 is 40 per cent higher in the scenarios in which the World Bank loan is mainly invested into irrigation infrastructure, since this increases the agricultural water demand. However, in 2050 there is no difference in water demand compared to the Base Run, since at this point irrigation infrastructure is the same in all four scenarios because the limit of 350,000 ha, maximum area that can be equipped with irrigation infrastructure, has been reached.

Table 8.13 indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework. It covers all aspects of the value chain and provides information on agriculture output and regulating services. It also provides estimate of impacts on natural capital especially water and land.

Table 8.13 Case study 9 (Senegal loans): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	Agricultural production	Manufacturing and processing	Distribution, marketing and retail	Household consumption
Outcomes (change in capital)				
Natural capital	Impact on land and water			
Produced capital				
Human capital				Nutrition Health Life expectancy
Social capital				Food security and Education
Flows				
Outputs				
Agricultural and food production	Food			
Income / operating surplus	Profits Taxes	Profits Taxes	Profits Taxes	Profits Taxes
Purchased inputs to production				
Labour	Wages	Wages	Wages	Wages
Intermediate inputs (fuel, fertilizer, etc.)	Irrigation Subsidies, Fertiliser use, pesticide use, seed etc.			
Ecosystem services				
Provisioning	Water Energy	Water Energy	Water Energy	Water Energy
Regulating	Water Soil fertility Organic matter			
Cultural				
Residual flows				
Food waste				
Pollution and emissions (excess N & P, GHG emissions, etc.)	GHG emissions	GHG emissions	GHG emissions	GHG emissions

🟩	Descriptive information available
🟧	Quantitative information available
🟦	Monetized information available
⬜	Not included in study

Policy questions that a TEEBAgriFood Framework-testing study can inform

The different scenarios presented suggest an interesting way to present decision trade-offs to policy-makers in a TEEB like analysis. The Threshold-21 (T21) simulation model applies economic valuation (direct market price) to many aspects in previous case studies that lack monetary values including water provisioning, food security, education, and GHG emissions. The application of the TEEB Framework to this study thus provides a tool that can aid policy makers in analyzing monetary investments, such as bilateral or multilateral loans.

- How does investing in inputs and infrastructure compare to investing in small scale producers and training, in terms of impacts on non-market ecosystem services?
- Can ecosystem services be monetized so that a common metric can permit more concrete analysis? Or would other quantitative or qualitative metrics be more suitable?
- Can the model be revised to more explicitly distinguish additional positive externalities, along with the evident negative ones such as GHG emissions? Education is considered; but further social variables such as social cohesion and cultural traditions of smallholder farming could also be considered (despite the challenge in terms of monetization).
- This analysis considered only a relatively small loan and its impact. What would be the outcome of applying the analysis at a larger scale, perhaps at the level of a national budget?

Lessons learned

This case study provided coverage across the food value chain and the impacts on National Accounts, while taking into account different ecosystem services, health impacts and social values. In this sense, it is one of the most complete studies to which to apply the TEEBAgriFood Framework. By including a comprehensive set of sectors and factors, the analysis can make many linkages that are hard to predict in more linear studies; for example, it demonstrates the positive impact of investing in training of smallholder producers rather than investing primarily in infrastructure when looking at social indicators such as employment, poverty reduction and food security. Based on a systems dynamics model, its greatest value is in a dynamic comparison of four competing models for policy makers.

CASE STUDY 10: Australian Environmental-Economic Accounts for agriculture

The Australian Bureau of Statistics (ABS) produces a set of environmental-economic accounts (Australian Bureau of Statistics 2017) each year measuring environmental assets (land, soil, timber, water resources), which increased 95 per cent over the period 2005-06 to 2014-15 from $2,999.5 billion to $5,837.5 billion. The value of Australia's produced capital also increased over this period, although to a lesser extent (70 per cent), rising from $3,276.7 billion to $5,564.1 billion. Environmental assets now make up the largest share of Australia's capital base, mainly in the form of land (83 per cent) and mineral and energy resources. Australian Environmental-Economic Accounts (AEEA) follow the System of Environmental-Economic Accounting 2012—Central Framework (SEEA Central Framework) for the evaluation of these assets. This multipurpose conceptual framework describes the interactions between the economy and the environment, and the status and changes in stocks of environmental assets (UN 2014). The SEEA Central Framework applies the accounting concepts, structures, rules and principles of the System of National Accounts (SNA), which uses Computable General Equilibrium (CGE) models that includes supply and demand across all sectors in an economy.

Here the environmental-economic accounts (Australian Bureau of Statistics 2017) related with agriculture sector and reflected in national accounts of Australia are summarised in **Table 8.14**, which indicates the coverage of this case study in accordance with the TEEBAgriFood Evaluation Framework. This study covered all aspects of the value chain and provided monetary estimates of changes in natural and physical capital associated with the agriculture sector in Australia. However, it did not provide any estimate of waste generated through the value chain or cultural services in agriculture.

Table 8.14 Case study 10 (Australia environmental-economic accounts): a checklist for scoping which elements of the TEEBAgriFood Evaluation Framework are assessed

Value chain	Agricultural production	Manufacturing and processing	Distribution, marketing and retail	Household consumption
Outcomes (change in capital)				
Natural capital	Land appreciation/ degradation			
Produced capital				
Human capital				Nutrition Health Life expectancy
Social capital				
Flows				
Outputs				
Agricultural and food production	Crops	Food	Food	Food
Income / operating surplus	Wages	Profits	Profits	Wages/profits
Purchased inputs to production				
Labour	Wages	Wages	Wages	Wages,
Intermediate inputs (fuel, fertilizer, etc.)	Irrigation Subsidies, Fertiliser use, pesticide use, seed			
Ecosystem services				
Provisioning	Water, Energy	Water, Energy	Water, Energy	Water, Energy
Regulating	Water, Soil fertility, Soil carbon	Water, Soil fertility, Soil carbon	Water, Soil fertility, Soil carbon	Water, Soil fertility, Soil carbon
Cultural				
Residual flows				
Food waste				
Pollution and emissions (excess N & P, GHG emissions, etc.)	GHG emissions	GHG emissions	GHG emissions	GHG emissions

🟩 Descriptive information available

🟧 Quantitative information available

🟦 Monetized information available

⬜ Not included in study

Policy questions that a TEEBAgriFood Framework-testing study can inform

This case study explores the importance of application of the Framework at macro level to capture value of natural capital in the national accounts. It can help address following policy questions.

- How can a national-level TEEBAgriFood analysis best be integrated into national accounts for natural capital or environmental assets? What kinds of policy guidance might this provide to decision makers?
- Alternatively, can a TEEBAgriFood analysis be carried out as an annual national statistical exercise, helping citizens to understand trends over time with ecological restoration activities as per the China Ecosystem Assessment case study?

Lessons learned

The case study of the Australian Environmental-Economic Accounts for Agriculture provides a very useful link to the concept of "stocks" or "natural assets" which the TEEBAgriFood Framework could profitably build upon. However, there is an underlying concept in these accounts that uses metrics reflecting concepts such as energy or water intensity to reflect the amount of resources used per unit of economic output. This same concept arises in the case study on grain-fed versus grass fed beef, above, in which one study argues that pasture fed beef from managed grazing systems is more "greenhouse gas intensive" per kg of meat produced than feedlot finished. Nevertheless, we note that this calculation, and the calculations in the Australian national accounts, are made on a per unit of product basis. Industrial agriculture will always perform better than more agro-ecological approaches when emissions are expressed on per kg of produce, given the higher levels of productivity of the former in the global scheme of agricultural production. Yet what causes global warming is the total net emission of greenhouse gases per area, regardless of yields. Thus, we would caution against solely using metrics reflecting efficiency, and urge that metrics always consider the totality of negative (and positive) externalities and their impacts.

8.4 SOCIAL INEQUITIES

The impacts of eco-agri-food systems are not homogenous across an entire society, and depend on factors including gender, culture and income. Building on Chapter 5's look at equitable food systems and drivers for change, we have elaborated on inequities concerning social impacts that can occur at various stages in the value chain (production, processing and distribution, and consumption). Here, we draw attention to how impacts affect societal groups differently, and how this should be reflected in applications of the TEEBAgriFood Framework.

8.4.1 Production

Equity requires that no social groups fall below minimum standards of environmental health (e.g. water quality for all communities should not fall below the standards). Chapter 4 gives an overview of occupational health hazards of agriculture. These health effects are variable depending on exposure rates as well as individual sensitivity. Health hazards are also affected by type of farming activity, type of worker, geographic location, inequities in health service and other social inequalities (such as wealth, education, and training). Chemical exposure and protection of farm workers also varies widely between developing and developed countries. Data from the 1990s show that developing countries account for 20 percent of all pesticide use, while more than 99 percent of human poisoning related to pesticides took place in developing countries (Cole 2006). This is highlighted in case study 7 on pesticide taxes in Thailand, where: i) externalities of pesticide use on farmworkers is ten-fold that of consumers, and ii) pesticide use has increased six-fold from 1987 to 2010 (a trend much more pronounced in developing countries).

Greenhouse gas (GHG) emissions, as potent contributors to climate change, are included as part of the TEEBAgriFood Framework and differences in emissions levels are among the indicators noted in the rice and beef studies explored in above sections. Agriculture's contribution to GHG emissions and climate change is increasingly acknowledged. As noted here, the production of animal protein and rice are both known to potentially emit high levels of greenhouse gases; levels that can be in some measure mitigated by adopting specific practices or production systems. However, in other respects, the sheer quantity of consumption of product such as meat-with a long "greenhouse gas" shadow suggests that the most important mitigation measure is further along the food value chain, in rebalancing diets and reducing the per capita consumption of meat in developed countries. In terms of social equity, the costs of climate change fall heavily on small-scale farmers and fishers in developing countries, both in terms of impacts and capacity to adapt to those impacts.

8.4.2 Processing and distribution

The processing and distribution phase of food systems impact society unequally, both in developed and developing countries. Many farmers are unable to make a living out of farm income alone, which affects family needs such as health care and social security. Access to income generating opportunities in the processing and distribution aspects of food systems is often critical for household incomes. However, as noted for example in the grass-fed versus grain-fed beef case study, processing facilities such as large-scale beef feedlots are often located in low-income neighbourhoods. This can provide much needed employment but also generate significant air and water pollution. Similarly, the social value of access to affordable food for all consists of several inequities such as trends in undernourishment and access to food between and within countries. For instance, poverty rates are often higher in rural areas than urban areas while the urban poor may be more sensitive to (changes in) food prices.

8.4.3 Consumption

In Chapter 4 the variability of social impacts related to food consumption is explored. The link between food access, food security and nutrition is discussed (e.g. access to food from supermarkets vs informal markets). Changes in diets are also considered in two case studies in this chapter; however, having convenient access to a variety of diet options is often a luxury associated with relatively high incomes; food "deserts" where mostly processed food is available is the reality in many low-income areas. The resulting issues of food access and malnutrition can severely affect children and the more vulnerable.

8.5 CHALLENGES AND LIMITATIONS

In this chapter, we showcased ten applications of the TEEBAgriFood Evaluation Framework to the existing set of case studies in an exploratory way. In doing so we have identified some challenges in each of the five families of applications.

There are not many known examples where the Framework is applied comprehensively. Therefore, we have only been able to demonstrate limited aspects of the Framework and have commented on its use to inform practice and policy accordingly. Agricultural production is not studied comprehensively across how food products are processed, distributed or used. The primary focus has long been on increasing productivity. This leads to partial assessment of sustainability. A comprehensive framework can help resolve these issues. Similarly, for the analysis of products, diets, policy and national accounts, there is little emphasis on the entire value chain. Therefore, research must be reprioritized to help better plan for future analysis that considers the entire value chain in order to evaluate all stocks of capital (natural, social, human) and flows (of ecosystem services and other inputs or outputs) in the agriculture sector. The case studies also reveal several 'gaps' in the Framework (i.e. unfilled boxes in showcased examples) that require future research.

Data gaps exist for each of the examples highlighted in the chapter not only because of the need for more research but also because the case studies were not designed to reflect flows of ecosystem services and different capitals through the entire value chain. For example, under agricultural management systems, selected studies focused on identified ecosystem services and not on natural, social or human capital. Products (palm oil and beef) highlighted in the chapter also have some focus on impacts on consumer's health and animal health but not all aspects are covered. In the two examples related to policy evaluations, there is need to collect data on the impact on different capitals and ecosystem services and to explore alternatives.

At this stage in the development of the TEEBAgriFood Framework and our understanding of the literature, there is no single study that provides a complete picture of how the Evaluation Framework can be applied comprehensively. However, the examples included provide sufficient evidence that a comprehensive study through the entire value chain can enhance potential development of sustainable agricultural and food systems. This information then can be used to inform policy for appropriate response at local, national and global level. From the case studies presented in this chapter, and by way of example, the potential utility of the framework to policymaking has been indicated in the following instances:

Agricultural management systems: Policy makers can employ the TEEBAgriFood Framework to understand the extent to which a specific production system (such as organic farming) minimizes negative externalities on water resources, while generating sufficient yields and other benefits, and how this might be supported through greater farmer training.

Agricultural product: Policy makers can employ the TEEBAgriFood Framework to evaluate the value, throughout the food chain (thus for producers, but also communities living near processing plants, and consumers) of alternative, low-impact ways of creating agricultural products.

Dietary comparison: A TEEBAgriFood analysis permits policy makers to consider issues of environmental sustainability of diets, along with nutrition and social equity. For instance, some studies suggest that having a component of grass-fed meat in a diet can be more sustainable, in environmental terms, than a purely vegetarian diet (Peters *et al.* 2016)

Policy evaluation: One way of "costing" negative externalities may be through taxes, such as a pesticide tax, or a soda tax. Generally, these are formulated to address one issue: pollution, or obesity for example. A TEEBAgriFood assessment permits policymakers to understand where, along the food value chain, multiple costs as well as benefits are occurring. Thus, policy makers can better understand where measures to address costs might be applied, in a more holistic manner, to provide incentives for transitions to systems with benefits in multiple dimensions.

National accounts: There are increasing efforts to bring natural capital accounting into the national agriculture and food sector in order to assess multiple forms of capital beyond simple measures of yield and productivity.

Realizing these potential uses, however, will require considerable effort and time, which has not been fully estimated. However, there is need to consider resources and capacity development while suggesting the application of the TEEBAgriFood Evaluation Framework.

Limitations

In addition to the above data gaps and research priority challenges, there are several limitations for populating the Framework, which are mentioned below.

- There is need to understand risks and uncertainties in the application of the Framework to agribusiness, government sector, consumers and research. The Framework in its current form provided as a universal tool, which can be applied in various situations. It is expected that with each application, the Framework will be modified to manage risks associated with degradation of natural, social and human capitals.
- There is need for policies to adopt the Framework at micro (e.g. farm level) or macro (e.g. landscape or regional) level. It is expected that comprehensive applications of the Framework will help trigger the right policy response.

8.6 CONCLUSIONS

The examples highlighted in each of the five families of application demonstrate various aspects of the eco-agri-food value chain along with its positive and negative externalities. It can be concluded that the Framework has potential to be a useful tool to develop appropriate policy response by exploring the entire agriculture and food value chain and recognising, demonstrating and capturing the value of all ecosystem services in eco-agri-food systems. An initial exploration through existing case studies helps showcase various challenges and limitations of the Framework, and provides insights about modifications and adaptation that will be required to fully realize the potential usefulness of the Framework. The explorations within this chapter are an introduction to a process that will continue, as lessons are learned with each application of the Framework. Through applying the Framework and bringing the results into policy making arenas, it will be possible to identify and address the significant externalities that distort the current economic system around agriculture and food. Such an analysis can be the essential groundwork for applying a Theory of Change, as elaborated in Chapter 9 to follow.

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