Chapter 2
Economic Sustainability

David Kraybill

Abstract Lively debate has occurred among environmentalists over the past three decades about whether economic systems can be treated as independent of environmental systems. The mainstream economic view is that man-made inputs and natural resources are highly substitutable through technological innovation, and therefore economic analysis can proceed without reference to environmental stocks and flows. This assumption is increasingly untenable as climate change brings major changes in global and local economies. To meaningfully analyze the sustainability of economic systems, many analysts now use research frameworks that are conceptually rigorous with regard to both economic and natural systems. Understanding the nature and complexity of capital (assets) is an important step in analyzing economic sustainability. Emerging notions of capital toward the end of the 20th century included natural capital. A growing number of environmental analysts are attempting to incorporate these expanded notions of capital into theory and practice. Using the concept of natural capital, it is possible to analyze the sustainability of human and natural systems and to assess the impact of economic activity, including agriculture, on future generations as compared to the present generation. This chapter presents an overview of research approaches that attempt to incorporate both economic and environmental systems for the study of sustainability with a focus on relevance of these methods for the study of African agriculture.

D. Kraybill (✉)
The Ohio State University, Columbus, USA
e-mail: kraybill@iagri.org

D. Kraybill
Innovative Agricultural Research Initiative, Morogoro, Tanzania

R. Lal et al. (eds.), *Climate Change and Multi-Dimensional Sustainability in African Agriculture*, DOI 10.1007/978-3-319-41238-2_2

2.1 Introduction

A growing body of scientific evidence points to anthropomorphic causes of climate change (Oreskes 2004; Cook et al. 2013). As the evidence mounts that human activity contributes to climate change, it would foolish to continue to treat the economy as though it were independent of the biological and chemical processes that create and sustain the organismic life on planet Earth.

The objective of this chapter is to present alternative conceptual models of the economy with regards to its relationship with natural and social systems. The paper begins with the standard neoclassical model of the economy and proceeds to present alternative frameworks in which the economy is embedded within the natural environment. Three distinct research paradigms aiming to develop integrated models of natural and human systems are discussed.

Climate histories constructed by scientists for ancient and modern periods reveal that major shifts in climate can have calamitous effects that result in altered trajectories of life on Earth. Because of the potential path-altering effects of climate change, both scientists and laymen increasingly ask how current economic practices will affect the conditions for life in the future. The extent to which today's actions affect the world of tomorrow has come to be known as "sustainability".

What is sustainability? Solow (1991), a Nobel Prize-winning economist, defines *sustainability* broadly as a moral imperative: "An obligation to conduct ourselves so that we leave to the future the option or capacity to be as well off as we are." Costanza and Patten defined a *sustainable system* as a system that survives or persists over time. Anand and Sen (2000) defined *sustainable development* as "non-declining welfare," where welfare is measured either as utility (satisfaction) or income.

For the purpose of this chapter, I define *economic sustainability* as the preservation, replacement, or expansion of produced and natural capital so that the economy is able to generate non-declining welfare in the future. This definition is generally consistent with the definitions in the previous paragraph but it adds the notion of capital, which is a key concept for linking the actions of today with well-being in the future.

2.2 A One-Dimensional View of the Economy

Economic theories and studies can be categorized broadly into two types: whole-system analysis and partial-system analysis. For many decades and continuing today, students in most introductory economics classes are presented with a whole-system model of the economy known as the "circular flow diagram" (Fig. 2.1) in which factors of production (capital, labor, and land) are provided by households to firms that produce goods which are then sold to households. In the circular flow diagram, the natural environment makes only a minor appearance, showing up as "land". This is a catch-all term that includes soil, water, forests, and

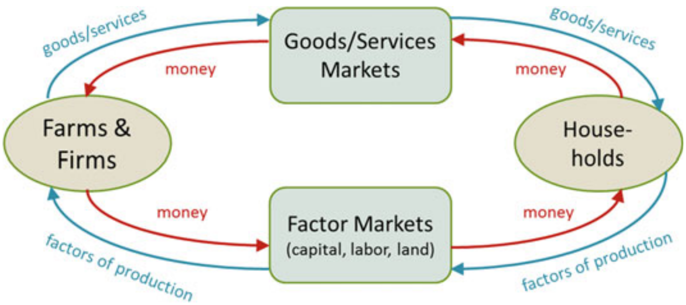

Fig. 2.1 The neoclassical circular flow diagram of the economy

other natural resources, but only those resources that are exchanged in markets. Omitted from this framework are natural resources that not traded in markets either because they are so abundant that they have no market value, as in the case of air, or because their use is not regulated by ownership-defining property rights. From an environmental sustainability standpoint, the absence of a mechanism for valuing nontraded natural resources is an important omission in the circular flow diagram, and one that is particularly relevant when considering issues of climate change.

A second important omission in the circular flow diagram from a sustainability standpoint is the absence of environmental "bads", which are generated as byproducts of human activity (Georgescu-Roegen 1971; Daly 1985). The diagram, which focuses on the economy in isolation from the natural environment, ignores the possibility that the economy may harm the natural environment and that this harm may, in turn, create harm to the economy. In essence, the circular flow diagram of the economy depicts the economic system as free from feedback from the natural environment.

While the complete absence or, at best, naïve representation of the natural environment that characterizes the circular flow diagram is evident in virtually all economy-wide analyses in mainstream economics, a separate branch of economics began to emerge more than 50 years ago to deal with problems of the environment. Environmental economics is a set of concepts and tools for analyzing environmental goods and services through partial-system analysis. Key among these concepts are market failure and time discounting.

The concept of market failure is relevant in situations where environmental goods, sometimes referred to as ecosystem services, or environmental bads are not traded in markets or where there are nonexistent or weak property rights to define ownership or responsibility for actions affecting the environment. Market failure also occurs where there are shared goods, such as a stable climate or community pastures, for which it is difficult or impossible to hold individuals accountable for how their actions affect the ecosystem services generated by these goods. A major focus of environmental economics is the imputation of the economic value of environmental goods and services where market failures occur so that gains and losses that are not formally recognized in market transactions are nevertheless taken into account by economic actors through governance processes. Market failures, if not addressed, threaten sustainability. Stern (2006), in his book on *The Economics of Climate Change*, asserts that "Climate change is the greatest market failure the world has ever seen."

Time discounting addresses future consequences of today's actions through the "social discount rate," which is the relative valuation that society places on the wellbeing of people today versus the wellbeing of people in the future. A zero discount rate implies future generations are treated the same as the current generation, while a positive discount rate implies the wellbeing of future generations matters less than the wellbeing of the current generation.

The concepts of market failure and time discounting have been used widely by mainstream economists to analyze the causes and consequences of economic activities that generate greenhouse gases. Based on these analyses, numerous solutions to curb greenhouse gases have been proposed, including emission trading schemes, carbon taxation, and transfer payments. Critics of environmental economics point out that analysts working in the mainstream tradition tend to treat the environment as a subsystem of the economy, using models and frameworks that fail to account for the complex dynamics of ecosystems. These dynamics are important for environmental sustainability but they are also important for economic sustainability if the environment and the economy are, in fact, interlinked.

Various economists have developed economic-environmental models, most of which are based on neoclassical economic theory with selected environmental flows appended. For example, the ENV-Growth model developed by OECD (2016) is a neoclassical growth model with three conventional drivers of change: exogenous technical change, changes in physical capital, and changes in the quantity and quality of labor. To this mainstream economic model, its creators have added two environmental drivers of growth: energy and natural resources, both modeled as economic flows (supply-demand and income-revenue); there is no attempt to model the biological and chemical systems from which energy and natural resources are derived.

2.3 Interlinked Human and Natural Systems

Representing interactions between human and natural systems in a formal model is difficult because the phenomena on which each of these systems focus operate at different spatial, temporal, and organizational scales. Consequently, the scholarly disciplines historically associated with these two systems, human and natural, use distinct concepts, methods, and tools of analysis that make conversation across disciplines a challenge. Despite these difficulties, over the past two decades, three groups of scholars have emerged with the aim of modeling human and natural system interactions using interdisciplinary and transdisciplinary frameworks that aim to embody fundamental principles of both ecosystems and human behavior. One of these scholarly groups is known as ecological economics, the second operates under the rubric of coupled human and natural systems, the third identifies its work as integrated assessment, and the fourth calls its approach sustainable livelihoods.

Sustainability is one of the central themes of the founders of ecological economics (Constanza et al. 1991) and the approach is generally transdisciplinary. Scholars affiliated with this group hold advanced degrees in a variety of disciplines, including ecology, economics, and philosophy. One of the major contributions of ecological economics is the development and application of tools for valuing natural capital, defined as bio-physical and chemical assets produced by nature. Among the tenets of ecological economics is the idea that produced capital has very limited capacity to substitute for natural capital, and therefore damage to the environment has major consequences for both natural and economic systems. In a paper published in *Nature*, Costanza et al. (1997) estimated that the annual value of global ecosystem services exceeds the annual value of global GDP as it is conventionally defined. Half of the value these authors impute for ecosystem services is related to nutrient recycling. Given the enormous value generated by nutrient flows, it follows that economic models that fail to account accurately for nutrient flows are inadequate tools for understanding and analyzing sustainability.

Created within the ecological economics tradition, an integrated human-ecosystem simulation model developed by Low et al. (1999) is based on the assumption that the stock of natural capital is jointly influenced by natural capital growth and depletion, ecological fluctuations, harvest rules, and biological transfers across ecosystems. Basic principles of both ecosystems and human systems are built into the model, which the authors use to analyze natural resource harvest patterns and the effect of resource movement across ecosystems. They conclude that inter-ecosystem movement reduces the threat of human-system collapse but can threaten the viability of ecosystems from which resources migrate.

According to Daly and Farley (2011), it is a tenet of ecological economics that the economy is "an open subsystem of a larger ecosystem that is finite, nongrowing and materially closed." Figure 2.2 is an environmental-economic model consistent with this view of the primacy of the ecosystem relative to the economic system. The stock of natural capital generates ecosystem services, some of which are used by producers and consumers. An important service of the ecosystem is to regenerate itself but this capacity is diminished by flows of pollution arising from economic activity. Natural capital is an important input into the making of goods and services but it is viewed as having a relatively low degree of substitutability with respect to physical capital or labor, a perspective known as "strong sustainability". The stock of natural capital is depreciated by the pollution generated by producers and consumers.

The extent to which ecological economics has adopted the methodological pluralism to which its founders aspire is debatable. Anderson and M'Gonigle (2012) contend that ecological economics, 20 years after its launch, has failed to deliver on its promise to move beyond the narrow confines of neoclassical economics and address seriously the ecological and political economy dimensions of the environment.

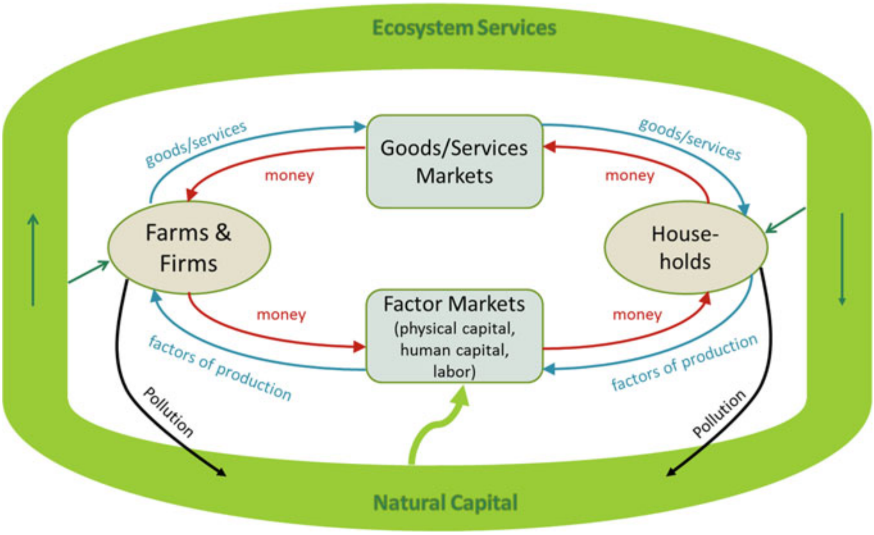

Fig. 2.2 The economy as a sub-system of the natural environment

Coupled human and natural systems (CHANS), a second major strand of international scholarship devoted to multidisciplinary analysis of sustainability, is arguably more equitably balanced than ecological economics in its treatment of ecological and human systems. According to McConnell et al. (2009), "what distinguishes the CHANS approach is an explicit acknowledgement that human and natural systems are coupled via reciprocal interactions, understood as flows (e.g., of material, energy, and information)." CHANS focuses on system complexity arising from feedback loops, nonlinearity and thresholds, legacy effects, and heterogeneity but also incorporates aspects of human behavior (Liu et al. 2007).

In 2007, the National Science Foundation (NSF) in the United States launched a formal program of funding for CHANS research. NSF restricts its funding to CHANS proposals that incorporate four elements: (1) dynamics of a natural system; (2) dynamics of a human system; (3) processes through which the natural system affects the human system; and (4) processes through which the human system affects the natural system.

The CHANS approach applied to African agriculture is illustrated by a research framework developed by Olson et al. (2008) to analyze two-way interactions of land use change and climate change. The framework consists of sub-models of land use change, agricultural productivity, land cover, and climate. Data were gathered from case studies, satellite, and secondary sources. A version of the framework was used to analyze the interaction of food production, land use and land cover, and climate change in East Africa (Moore et al. 2012). The model reveals that both climate change and land cover/land use are capable of bringing about significant changes in food production, though for a given exogenous change in climate or land cover/land use, the food production response varies enormously across the East African landscape.

A third interdisciplinary approach to analysis of the economy and the environment is known as integrated assessment. According to Center for International Earth Science Information Network (CIESIN 1995), the two defining characteristics of integrated assessment are "(1) that it seeks to provide information of use to some significant decision-maker rather than merely advancing understanding for its own sake; and (2) that it brings together a broader set of areas, methods, styles of study, or degrees of certainty, than would typically characterize a study of the same issue within the bounds of a single research discipline". Scholars of integrated assessment typically work in teams of experts from the disciplines of economics, political science, engineering, ecology, climatology and other disciplines to jointly construct integrated assessment models (IAMs) with physical and social science sub-models. Typically, within an IAM, the physical sub-model simulates climate while the social science sub-model simulates the economy.

IAM researchers are well organized and have been able to attract significant amounts of funding. An international organization, the Integrated Assessment Modeling Consortium (IAMC), was created in 2008 and holds annual meetings. Major funding for IAM research has been provided by governments of the United States, Netherlands, Japan, from foundations, and various other sources.

IAMs have been used to analyze the causes and consequence of climate change in Africa. For example, the ADAPTCost Project of the United Nations Environmental Program (UNEP) has been used to estimate the economic cost of climate change in Africa (United Nations Environment Program 2010). IAMs have been applied to the study of the interaction of climate change and agriculture (Valdivia et al. 2015). An international research initiative, the AgMIP Sub-Saharan Africa Regional Coordination Project, is developing agriculture-focused modules to be used with regional IAMs on Africa.

2.4 A Sustainability Framework for Extension and Outreach Practitioners

The integrated models described in the preceding sections are useful for research and policy-making on sustainability but they provide little specific guidance to practitioners working directly with farmers and farming communities. For the design of specific policies and programs, a less formal sustainability framework is needed to guide the practitioner. Such a framework is provided by the Sustainable Livelihoods (SL) framework.

For economies with poor, vulnerable populations engaged in informal employment, "livelihood" is a useful concept for analyzing multi-dimensional sustainability at the household level. According to Chambers and Conway (1991), "a livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term."

The SL framework addresses environmental, economic, social, and institutional sustainability by analyzing expected or actual changes in the assets on which the household's livelihood is based. The livelihood assets on which SL analysts typically focus are physical, natural, human, social, and financial assets. The aim of the framework is to deepen understanding of the "vulnerability context" through which economic, political, social, and natural change can diminish the grip of households on their assets. Change is sustainable when it gives a household greater command over one or more of its livelihood assets without diminishing its other livelihood assets or the livelihood assets of other households. The household's asset portfolio determines the kinds of strategies available to the household for obtaining its livelihood. Figure 2.3 identifies various rural household strategies in developing countries. The particular strategies chosen by the household determine the livelihood outcomes it is able to reap. Outcomes are measured in terms of both the level and variability of well-being. The household's livelihood outcomes in the current period have implications, positive or negative, for its well-being in the next period. Good outcomes this year lead to greater assets next year. Bad outcomes this year lead to reduced assets next year, threatening the sustainability of the household.

The SL approach has been used widely by scholars and practitioners to undertake integrated, multidisciplinary analysis of the likely effects of climate change on

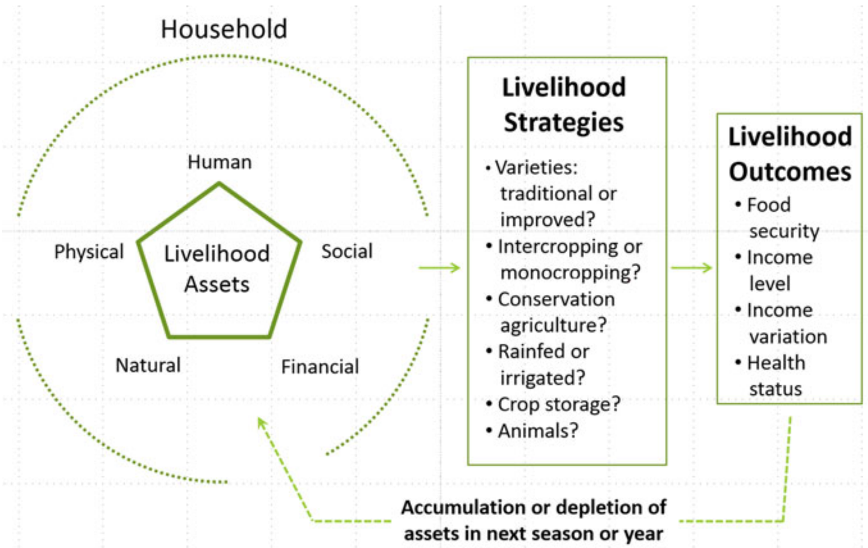

Fig. 2.3 Sustainable livelihoods framework

agricultural households. Connolly-Boutin and Smit (2015) reviews applications of the SL approach to the study of climate change in Africa.

2.5 Conclusion

In summary, analytical frameworks available for analyzing the economics of agriculture in Africa have expanded from economics-only theories and models to multidisciplinary and transdisciplinary models. In some of these frameworks, the economy is a sub-system of a larger, natural system while in others the economy is treated as the dominant system to which the natural system is appended. Ecological economics, coupled human and natural systems (CHANS), integrated assessment modeling (IAM), and the sustainable livelihoods (SL) approach all aim to take into account linkages between the economy and the environment, though the featured interactions among these systems vary across the approaches and even across studies within each of these approaches. All four approaches have been applied usefully to the study of sustainability of African agriculture.

References

Anand S, Sen A (2000) Human development and economic sustainability. World Development 28 (12): 2029–2049

Anderson B, M'Gonigle M (2012) Does ecological economics have a future? Contradiction and reinvention in the age of climate change. Ecol Econ 84:37–48. doi:10.1016/j.ecolecon.2012.06.009

Chambers R, Conway GR (1991) Sustainable rural livelihoods: practical concepts for the 21st century. IDS discussion paper 296. Institute of Development Studies, University of Sussex, Brighton

Connolly-Boutin L, Smit B (2015) Climate change, food security, and livelihoods in Sub-Saharan Africa. Regional environmental change. Springer, Berlin, pp 385–399

Consortium for International Earth Science Information Network (CIESIN) (1995) Thematic guide to integrated assessment modeling of climate change. CIESIN, Palisades. http://sedac.ciesin.org/mva/iamcc.tg/TGHP.html

Constanza R, Daly H, Bartholomew J (1991) Goals, agenda and policy recommendations for ecological economics. Environ Accoun Sustain. doi:10.1055/s-0029-1214156

Cook J, Nuncatelli D, Green SA, Richardson M, Winkler B, Painting R, Way R, Jacobs P, Shaw A (2013) Quantifying the consensus on anthropogenic global warming. Environ Res Lett 8:24–31

Costanza R, Arge R, De Groot R, Farberk S, Grasso M, Hannon B, Limburg K et al (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260. doi:10.1038/387253a0

Daly HE (1985) Matter-energy: a case of misplaced concreteness. Rev Soc Econ 43(3):279–297

Daly HE, Farley J (2011) Ecological economics: principles and applications. Island Press, Washington

Georgescu-Roegen N (1971) The entropy law and the economic process. Harvard University, Cambridge

Liu J, Dietz T, Carpenter SR, Alberti M, Folke C, Moran E, Pell AN et al (2007) Complexity of coupled human and natural systems. Science 317(5844):1513–1516. doi:10.1126/science.1144004

Low B, Costanza R, Ostrom E, Wilson J, Simon CP (1999) Human-ecosystem interactions: a dynamic integrated model. Ecol Econ 31(2):227–242. doi:10.1016/S0921-8009(99)00081-6

McConnell WJ, Millington JDA, Reo NJ, Alberti M, Asbjornsen H, Baker LA, Brozović N et al (2009) Research on coupled human and natural systems (CHANS): approach, challenges, and strategies. Bull Ecol Soc Am 92(2): 218–228

Moore N, Alagarswamy G, Pijanowski B, Thornton P, Lofgren B, Olson J, Andresen J, Yanda P, Qi J (2012) East African food security as influenced by future climate change and land use change at local to regional scales. Clim Change 110(3–4):823–844. doi:10.1007/s10584-011-0116-7

OECD (2016) Environmental-economic modelling. http://www.oecd.org/environment/indicators-modelling-outlooks/modelling.htm

Olson JM, Alagarswamy G, Andresen JA, Campbell DJ, Davis AY, Ge J, Huebner M et al (2008) Integrating diverse methods to understand climate-land interactions in East Africa. Geoforum 39(2):898–911. doi:10.1016/j.geoforum.2007.03.011

Oreskes N (2004) The scientific consensus on climate change. Science 305(5702):1686

Solow RM (1991) Sustainability: An economist's perspective. The Eighteenth J. Seward Johnson Lecture, Marine Policy Center. Woods Hole, MA: Woods Hole Ocenographic Institution, June 14, 1991

Stern N (2006) The economics of climate change. Stern Rev. doi:10.1257/aer.98.2.1

United Nations Environment Program (2010) ADAPTCost project : analysis of the economic costs of climate change adaptation in Africa

Valdivia RO, Antle JM, Rosenzweig C, Ruance AC, Vervoot J, Ashfaq M, Hathie I et al (2015) Representative agricultural pathways and scenarios for regional integrated assessment of climate change impact, vulnerability and adaptation. In: Hillel D, Rosenzweig C (eds) Handbook of climate change and agroecosystems: the agricultural model intercomparison and improvement project (AgMIP). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150009315.pdf

http://www.springer.com/978-3-319-41236-8

Climate Change and Multi-Dimensional Sustainability in African Agriculture
Climate Change and Sustainability in Agriculture
Lal, R.; Kraybill, D.; Hansen, D.O.; Singh, B.R.; Mosogoya, T.; Eik, L.O. (Eds.)
2016, XXIV, 717 p. 165 illus., 144 illus. in color., Hardcover
ISBN: 978-3-319-41236-8