Ecological Farming Literature Review

Katherine Killebrew, Professor Alison Cullen,
& Professor C. Leigh Anderson

Prepared for the Farmer Productivity Team of the Bill & Melinda Gates Foundation

Evans Policy Analysis and Research (EPAR)
Professor Leigh Anderson, PI and Lead Faculty
Associate Professor Mary Kay Gugerty, Lead Faculty
Ryan Gockel, Lead Research Analyst

November 9, 2009

Overview

Ecological farming and conventional farming are two approaches to producing food. The term "ecological farming" describes a range of agricultural systems that seek to provide food and environmental and social benefits by using natural processes and local resources rather than off-farm, purchased inputs (commonly referred to as "external inputs"). Recent debate about the merits of ecological farming over conventional methods has centered on each system's ability to increase production in the context of numerous and varied biophysical and social constraints. A review of the literature suggests that ecological farming can offer some benefits to smallholder farmers, but that specific approaches must be tailored to local climate and soil conditions and availability of labor, training, and organic inputs.

Defining "Ecological Farming"

No standardized definition of ecological farming or conventional farming exists, but most scholars distinguish the methods based on differing approaches, techniques, inputs, and goals (Table 1). "Conventional farming" implies the use of modern, Green Revolution technologies and inorganic external inputs, such as transgenic, high-yielding seed varieties; water from irrigation systems; chemical fertilizers and pesticides; and mechanization (Graves et al., 2004; Pender & Mertz, 2006). Another common term for conventional farming is high external input agriculture (HEIA).

Conventional farming focuses on managing problems within the crop field, such as soil nutrients and pest outbreaks, with overarching goals to increase yields and productivity. Hecht (1995) describes this method as a "target approach," in which the purpose of the agricultural system is purely on production. Techniques associated with conventional farming include monocropping, application of inorganic fertilizers and pesticides, construction of irrigation systems, use of genetically modified seeds, and use of mechanical equipment such as tractors (Borlaug, 1992; Fernandes et al., 2005).

"Ecological farming" is a broad descriptor for agricultural methods that seek to be more sustainable than conventional farming by avoiding negative unintended natural and social consequences. The concept of time is central to ecological farming's definition. In reaction to conventional farming's implicit focus on the current period, ecological farming takes a long-term view. By using assets in a way that does not deplete them, ecological farming aims to maintain productivity and usefulness to society in perpetuity (Pretty, 1999; Rigby & Caceres, 2001). Supporters of ecological farming question the long-run viability of conventional farming methods, such as the use of non-renewable energy sources and dependence on a narrow genetic base (Rigby & Caceres, 2001).

Ecological farming includes many systems and techniques, all involving the reduction or elimination of inorganic inputs. Instead of chemical fertilizers and pesticides, ecological farming and similar methods use natural processes and locally available resources to manage crop fields. Techniques are generally very diverse and context-specific and may include: soil and stone bunding, terracing, and minimum tillage for soil conservation; cover crops, mulching, and crop rotation for soil fertility; planting basins, check-dams, ponds, tanks, wells, rainfed systems, and drip irrigation for water harvesting and delivery; and intercropping and hedgerows for pest and weed management (Shiferaw, et al., 2009; Lee, 2005; Hecht, 1995). Ecological farming techniques are based on both traditional and modern scientific knowledge (Ammann, 2008).

Ecological farming broadens conventional farming's focus on food production to also include environmental and social outcomes (Hecht, 1995). By using biological processes in place of off-farm inputs, ecological farming aims to improve soil conditions, diversify species and genetic resources, enhance beneficial biological interactions, recycle biomass, and minimize energy loss (Lee, 2005). Pretty (2008) argues that by using natural goods and services and local knowledge, sustainable agriculture encourages new social configurations based around leadership, trust, management skills, and the capacity to innovate. The approach is holistic rather than targeted solely on production (UNEP-UNCTAD, 2008). A summary of the distinguishing characteristics of ecological and conventional farming appears in Table 1.

Table 1: Characteristics of ecological and conventional farming

	Ecological Farming	**Conventional Farming**
Approach	Holistic approach	Target approach
Techniques	Polycropping, intercropping, cover crops, mulching, crop rotation, minimum tillage, use of natural parasitic relationships, construction of rainfed or drip irrigation systems	Monocropping, application of chemical fertilizers and pesticides, construction of irrigation systems, use of hybrid and transgenic seed varieties
Distinctive inputs	Intensive labor; access to manure or other organic fertilizers; education and training in ecological farming practices; adaptation of practices to local context	Physical and financial access to mineral fertilizers, synthetic pesticides, and improved crop varieties; irrigation sources or adequate rainfall
Goals	Sustain and enhance food production, environmental conditions, and social	Increase yields and productivity

	relationships in perpetuity	

An erroneous distinction commonly made between ecological and conventional farming is that ecological methods entail a net reduction in input use. Ecological farming shifts, rather than reduces, the factors of production, from fertilizers and herbicides to nitrogen-fixing cover crops, for example (Pretty, 2008). To be successful, ecological farming requires intensive inputs in the form of training and local adaptation of methods, labor, and natural fertilizers (Pender & Mertz, 2006). Halberg et al. (2006) describe ecological methods as "knowledge intensive" rather than input intensive, requiring that farmers have existing knowledge or receive training in managing integrated systems.

Parrott et al. (2006) note that agriculture systems characterized by a lack of external inputs are not ecological or organic by default. Resource-poor farmers farming without the use of chemical inputs are often doing so out of poverty and lack of resources, not due to a conscious choice to adopt an integrated, ecological approach.

Terms for systems that fall under ecological farming include sustainable agriculture, low external input sustainable agriculture (LEISA), limited external input agriculture (LEIA), and organic farming (Pretty, 2008; Pender & Mertz, 2006; Altieri, 1995). There is no widely accepted taxonomy for ecological farming systems, with some authors describing organic agriculture as a form of low external input sustainable agriculture and vice versa (FAO, 2007; Pender & Mertz, 2006). Others define the two as distinct systems with certain shared characteristics (Parrott et al., 2006). Figure 1 illustrates the categories and relationships of ecological farming systems according to the basic definitions that follow.

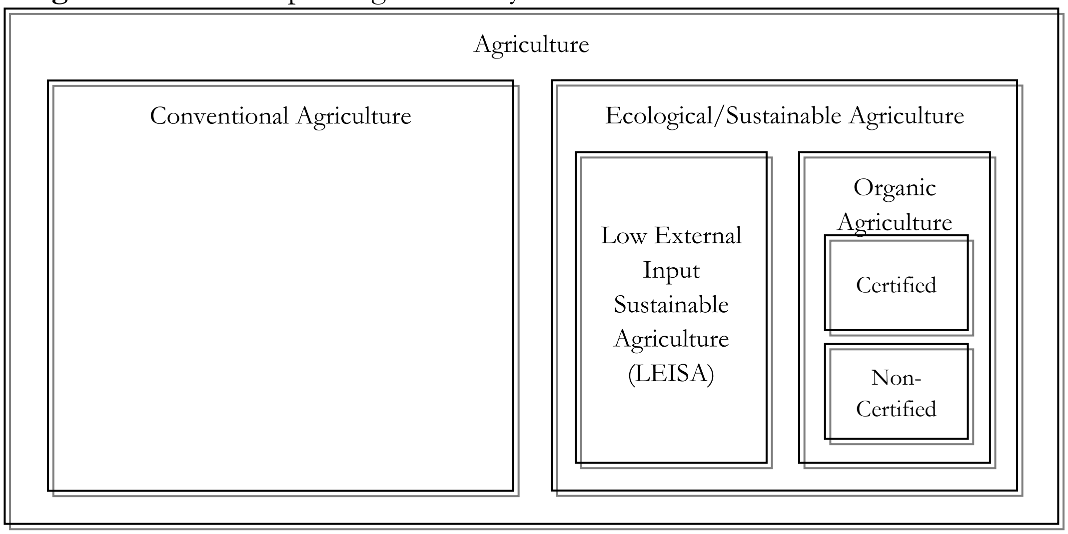
<u>Sustainable agriculture</u> makes the best use of natural goods and services without damaging ecological, social, and human assets (Pretty et al., 2003). In practice, sustainable systems are commonly considered to use less external off-farm inputs, employ improved management techniques, and use locally available natural resources and purchased inputs in an efficient, complementary manner (Lee, 2005). Like "ecological farming," the term "sustainable agriculture" is inclusive of many different types of farming systems.

<u>Low external input sustainable agriculture (LEISA) and limited external input agriculture (LEIA)</u> involve limited or no use of external inputs such as fertilizers, hybrid seeds, and pesticides. The ecological principles underlying these systems include: providing favorable soil conditions for plant growth by managing soil organic matter and enhancing soil biological activity; promoting nutrient availability through biological nitrogen fixation, nutrient recycling, and limited complementary use of inorganic fertilizers; minimizing soil losses by managing microclimates and water; and reducing pest and disease problems through integrated management (Reijntjes et al., 1992). While a seemingly significant difference between LEISA and organic farming is that LEISA allows "safe and efficient use of external inputs," Parrott et al. (2006) argue that the two systems are very similar in practice.

<u>Organic farming</u> is a production system that uses locally adapted cultural, biological, and mechanical methods rather than inputs with adverse effects (IFOAM, 2007). Organic agriculture includes both certified organic and non-certified organic agriculture (NC-OA). The WHO Codex Alimentarius

guidelines define global standards for certified organic agriculture. NC-OA farmers follow the same principles set out by the International Federation of Organic Agricultural Movements (IFOAM), but do not have their products certified.

Figure 1: Relationships of agriculture systems



Analysis of Ecological Farming in Africa

Literature examining ecological farming in Sub-Saharan Africa (SSA) generally falls under two lines of investigation. The first type examines the basic question of whether ecological farming methods have the potential to increase crop yield and productivity relative to status quo methods. Studies in this group seek to determine whether ecological farming can serve as a legitimate strategy for improving food security in developing countries. The second line of investigation assesses the factors that contribute to or hinder the adoption of ecological farming. These studies examine whether ecological farming is suited to the diverse and unique biophysical and socioeconomic conditions of SSA.

<u>Yield and Productivity</u>

A question debated by scholars is the extent to which ecological methods can increase agricultural production to feed Africa and the rest of the world. Critics of ecological farming claim that reducing the use of fertilizers and pesticides would dangerously limit food production and require the conversion of millions of hectares of natural habitat into farmland (Borlaug, 2000). Proponents of ecological farming argue that conventional methods are incompatible with conditions facing most SSA farmers and that recent studies demonstrate the potential for ecological farming to increase food production in developing countries (UNEP-UNCTAD, 2008).

Meta-Studies on Yields

Two peer-reviewed studies, Pretty et al. (2006) and Badgley et al. (2007), performed meta-analyses of several hundred farming cases to assess the impact on yields of adopting ecological farming systems. Pretty et al. (2006) analyzed yields from 286 sustainable agriculture projects in 57 developing countries. The research team purposively sampled agricultural projects representing all eight categories of FAO farm systems and used questionnaires and published reports to assess adoption of sustainable methods. The study measured yield changes using two methods: i) sampling some sites once in time to gauge yield differences between plots with and without ecological systems; and ii) sampling some sites twice over a four-year period to make before-after comparisons. The study did not describe how long sustainable methods had been in place when measurements took place.

Combining both types of sample data, the study found that crop yields increased 79 percent on average following successful conversion from traditional, "unimproved" farming methods to sustainable practices. Cassava/sweet potato, potato, and fruit and coffee crops demonstrated the largest yield increases. Cotton, rice, groundnuts, and soybeans made the smallest yield increases.

The study samples included farms adopting a diverse range of ecological techniques, from minimum tillage and agroforestry to integrated pest management and intercropping. Pretty et al. hypothesized that three types of underlying technical improvements played roles in increasing yields: (i) more efficient water use in both dryland and irrigated farming; (ii) improvements in organic matter accumulation in soils and carbon sequestration; and (iii) pest, weed, and disease control emphasizing in-field biodiversity and reduced pesticide use. Pretty et al. conducted similar studies in 2001 and 2003 that also found increased yields following the introduction of environmentally sensitive methods to traditional farming systems.

Additional evidence of increased food production comes from Badgley et al. (2007). The study evaluated the potential contribution of organic agriculture to the global food supply by calculating comparative yields between organic and non-organic methods. The research team compiled 293 published cases that compare yields from organic systems to systems using locally prevalent methods in both developed and developing countries. For developing countries, locally prevalent methods largely entailed non-intensive, traditional farming systems. Like Pretty et al. (2006), Badgley et al.'s study did not reveal how many years the organic farming systems had been in place.

The study found an average yield ratio of 1.80 for developing countries, meaning organic yield is potentially 180% that of yield from locally prevalent methods. A caveat to the study is that most of the developing world cases were taken from Pretty & Hine (2001). In the appendix, the authors ascribed this to the fact that in the developing world, "there are fewer controlled comparisons of organic versus non-organic methods than for the developed world."

A significant critique of the Pretty et al. and Badgley et al. studies is that they lack well-defined controls. Pretty et al. do not describe sampling methods in enough detail to allow an assessment of the use of controls, and Badgley et al. fail to acknowledge the need for controls. Without comparable control cases, the studies cannot directly attribute improvements in yield to the ecological farming methods. Other factors, such as improved access to credit and markets or better training and extension services, could also have contributed to the yield increases (Halberg et al., 2006; Phalan et al., 2007). The studies do not clearly reveal whether yield improvements were the result of the farming methods themselves, or simply the effect of concomitant changes. The studies also do not control for the length of time ecological farming methods had been in place.

Studies on Yields Over Time

Studies focusing on specific ecological farming techniques, such as agroforestry or conservation agriculture, highlight the importance of examining yield impacts over time. Many ecological farming practices take longer than conventional methods to improve food production (Mercer, 2004; Shiferaw, 2009). For example, farmers implementing agroforestry may need to wait three to six years before realizing the full benefits of the system. The complexity of agroforestry and other integrated systems means that farmers generally need more time to test and adapt new inputs and techniques than they do for conventional methods (Mercer, 2004).

Biophysical conditions may also cause delays in yield improvements from ecological farming. Giller et al. (2009) reviewed yield data from farms adopting conservation agriculture in SSA and reported no yield benefits and, in some cases, reduced yields in the short-term. Over longer periods (from six to ten years), yield responses were neutral to positive as conservation agriculture slowly arrested soil degradation and increased soil organic matter.

It has been argued that the time required to realize benefits from ecological farming may serve as a barrier to adoption. Farming methods that cause incomes to decline in the short-term are unlikely to be adopted, even if adoption may improve future incomes enough to compensate for initial losses. Unless subsidies are provided, most poor farmers cannot afford temporal income trade-offs (Shiferaw, 2009).

In the long-term, ecological farming methods may maintain yields more effectively than conventional methods. For example, high yielding seed varieties have produced dramatic maize yield increases in several SSA countries. Adoption of fertilizer, however, has lagged behind the use of high yielding seeds. Such stepwise technology adoption can lead to soil fertility depletion since high yielding seeds mine soil nutrients more rapidly than traditional seeds.

The combination of degraded soils and intensive chemical fertilizer use can also reduce yields over time. Land degradation processes, such as loss of soil organic matter and topsoil, decrease the efficiency of inorganic fertilizer inputs (Pender & Mertz, 2006). In long-term experiments in Kenya, maize yields declined 50 percent during a seven-year period under continuous cropping with inorganic fertilizer. Application of farmyard manure produced higher yields that declined less over time (Nandwa & Bekunda, 1998).

In parts of SSA with existing soil deficiencies, however, strictly organic farming methods may prove unfeasible in the long-term. Soils that are phosphorus fixing or phosphorous- and potassium-deficient may require processed or inorganic fertilizer to maintain production. Use of unprocessed phosphate rock is an organic fertilizer option for some areas, but phosphate rock deposits are spotty in SSA. Outside of West Africa, unprocessed phosphate lacks the reactivity needed to be useable for soil fertility replenishment (Pender & Mertz, 2006).

Studies on Productivity

Pretty et al. and Badgley et al. do not address the additional or re-configured inputs used to obtain increased yields on the ecological farms in their studies. Pretty et al. (2007) cite evidence of farmers' voluntary adoption of the ecological methods as evidence that the systems provided net benefits. If the practices did not increase economic well-being, then adoption of the systems would not have occurred.

Other studies on specific farming techniques use measures of returns to labor and gross revenues to assess the productivity effects of ecological farming. Hassanali et al. (2008) calculated the economic costs and benefits for smallholder maize farmers in Kenya who adopted the "push-pull" technique to manage pests. Push-pull uses intercropping to repel insects from a crop ("push") and attract them into trap crops ("pull").

The study collected cost and revenue data for push-pull farms and "farmer's practice" farms in six districts in Kenya in 2004. As displayed in Table 2, push-pull systems in all districts required higher labor and variable costs than farmer's practice systems, but total gross revenues were sufficient to offset costs. Gross benefits in push-pull systems were significantly higher than in the farmer's practice systems.

Table 2: Economics of push-pull strategy compared to farmer's practice systems in six districts in Kenya in 2004 (a, b, and c represent data averages for seven, four, and three years, respectively). All parameters in all districts were significantly higher in the push-pull systems

	total labor cost ($) ha		total variable cost ($) ha		total gross revenue ($) ha		gross benefit ($) ha	
district	push-pull	farmer's practice	push-pull	farmer's practice	push-pull	farmer's practice	push-pull	farmer's practice
Trans-Nzoia[a]	223	128	493	374	1,290	628	797	254
Suba[a]	167	134	278	250	679	329	401	79
Bungoma[b]	247	222	331	300	867	415	536	115
Busia[b]	222	118	321	243	862	418	541	175
Kisii[b]	184	140	246	210	733	334	487	134
Vihiga[c]	227	128	359	331	785	423	426	92

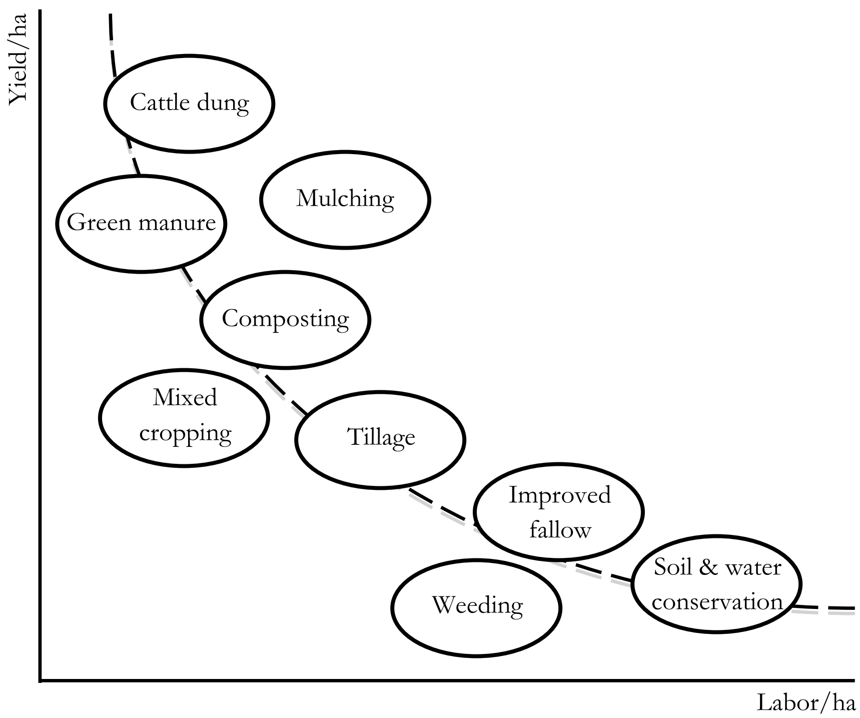
Source: Hassanali et al. (2008). (p<0.05)

A 2001-2002 study of 125 farms in Zambia assessed the yield and productivity impacts of adopting a package of ecological farming practices, including minimum tillage, planting pits, and crop residue retention. Combining data from a five-year period, the study found that cotton yields increased by more than 40 percent and maize yields by more than 30 percent, and that returns to peak season labor increased by 150 percent for cotton and 90 percent for maize (Haggblade & Tembo, 2003).

Although farmers adopting the ecological methods invested additional labor for preparing fields and weeding compared to traditional methods, yield gains were able to offset the added labor. Field preparation took place in the dry, off-season, thus relieving peak-season labor bottlenecks. Labor demands for land preparation were found to decline substantially over time, with fifth-year farmers requiring about half the labor days of a first-year farmer (Haggblade & Tembo, 2003).

Figure 2 represents the expected trade-offs between labor and yields for major ecological farming methods (Kuyvenhover & Ruben, 2002). The adoption of ecological farming techniques is likely to depend on the labor opportunity costs and output prices facing farmers. For example, soil and water conservation practices and intensive weeding are likely only attractive for crops with a high value, or in areas where labor costs are low. As described below, farmers dealing with labor constraints may find ecological farming methods infeasible.

Figure 2: Labor intensity and yield effects of major ecological farming practices.



Source: Kuyvenhover & Ruben, 2002.

A Note on Comparisons

With the exception of the Nandwa & Bekunda (1998) study examining the long-term impacts of fertilizer application in Kenya, an important characteristic of the yield and productivity studies is that they make comparisons between ecological farming methods and locally prevalent, resource-poor subsistence farming. Because conventional, high-input systems are uncommon in SSA, the studies do not attempt to uncover the potential yield and productivity effects of switching from high-input methods to ecological methods in developing countries. Instead, they compare status quo practices to the introduction of integrated, environmentally sensitive systems.

Studies examining the effects of converting high-input systems to LEISA and organic systems in developed countries have consistently found decreased yields and productivity. In Europe and North America, for example, high-yielding regions with optimal access to fertilizer and pesticides would experience yield declines of 15 to 35 percent if converted to organic systems (Halberg et al., 2006). The question of whether ecological agriculture methods will increase or decrease food production depends on the overall starting conditions of the farming system. Because most SSA smallholder farmers are starting from a condition of degraded soils and lack of access to modern inputs, ecological farming techniques have the potential to increase yields, as would lower cost access to more external inputs. The important question of whether ecological or technological solutions more effectively raise productivity in the short- and long-run has not been directly tested.

Suitability for Local Conditions

A second line of research investigates whether ecological farming is better suited than conventional farming to SSA's biophysical and socioeconomic conditions. Advocates of ecological farming argue that Green Revolution technology is incompatible with the resource constraints of most SSA farmers (Altieri, 1995). This type of argument is concerned less with the debate about yield and productivity, focusing instead on the factors that make smallholders more or less likely to adopt agricultural practices.

Lee (2005) and Shiferaw et al. (2009) provide conceptual frameworks for smallholder adoption of ecological practices and review evidence of the concepts working in practice. Both studies start from the viewpoint that ecological methods have the potential to increase food production in an environmentally sensitive manner, but that the challenges and opportunities for widespread adoption need to be better understood. The studies draw conclusions by examining cases from SSA and other developing countries.

Training, Research, and Management Capacity Requirements

Lee finds that a significant challenge for broad dissemination of ecological farming is the site-specific nature of LEISA and organic systems. Sustainable agriculture, by definition, seeks to make the best possible use of biological processes and local knowledge and skills (Pretty, 2008). Doing so requires that ecological farming techniques be "fitted to place," taking into account local agro-climactic conditions, resource availability, and human population conditions.

Given the heterogeneity of biophysical and social conditions in SSA, proponents of ecological farming contend that a customized approach is more appropriate than conventional farming's one-size-fits-all system. Lee notes several examples from SSA of ecological farming systems successfully addressing location-specific constraints or resource scarcities. Farmers in southwest Cameroon have used alley cropping systems rather than conventional bush fallow rotations to overcome fuelwood scarcity. In parts of East Africa, farmers have adopted leguminous fallow practices to address widespread soil fertility depletion.

However, the potential of ecological methods to address location-specific constraints depends upon the education level and management capacity of involved farmers and the availability of extension services. To adopt sustainable farming systems and adapt them to local conditions, farmers must have or be receiving training in observational, analytical, experimental, and communications skills. Without such training, farmers may be unable to properly manage the complex interactions of biological processes and will give up when the results predicted by experts fail to materialize (Halberg et al., 2006). Lee finds evidence that involving nongovernmental organizations, farmer-based organizations, outreach programs, and extension services in providing information and training to farmers significantly increases the successful adoption of sustainable agricultural practices.

Shiferaw et al. (2009) note the importance of involving farmers in the selection and adaptation of relevant techniques. Bottom-up, participatory approaches give farmers a chance to experiment and adopt various practices at their own pace and modify techniques according to changing conditions. The study contends that the ability of ecological farming to overcome local constraints hinges on the availability of education and training about selecting and implementing sustainable practices.

Several authors caution against over-emphasizing the knowledge intensity of ecological farming methods. Many LEISA and organic techniques build on traditional practices, such as crop rotation, fallowing, and use of manure. Farmers familiar with these techniques may find it relatively easy to adopt and adapt them to local conditions (Pender & Mertz, 2006). In addition, farmers have taken up new knowledge-intensive technologies quickly in the past, such as the rapid adoption of coffee cultivation following World War II in East Africa (Halberg et al., 2006).

Labor Requirements

Lee (2005) and Shiferaw et al. (2009) find that labor availability impacts the adoption of ecological farming techniques, which are typically more labor intensive than conventional methods. Tree planting, rainwater harvesting, mulching, making compost, and applying household waste and farmyard manure have high labor requirements (Parrott et al., 2006; Schlecht et al., 2006). To fertilize one hectare of maize with 100 kg of nitrogen, a farmer would need to apply more than 20 t of leaf biomass or manure, compared to only 217 kg of urea (Pender & Mertz, 2006).

Factors such as household size, family labor availability, access to labor markets, and the opportunity costs of labor may profoundly impact the feasibility of adopting ecological practices. When labor markets are missing or imperfect, empirical evidence shows that households endowed with more family labor will have an advantage in implementing labor-intensive practices (Shiferaw et al., 2009). Lee (2005) notes that increased off-farm and non-farm labor opportunities allow households to generate the liquidity necessary for investments in new ecological farming technologies, but may simultaneously reduce the possibility of adopting labor-intensive ecological practices.

Labor requirements can be serious obstacles for female-headed and HIV/AIDS-affected households, which face serious labor trade-offs between farming, education, and off-farm employment. In addition, farmers who own numerous fragmented fields or plots far from home may find labor requirements particularly problematic (Pender & Mertz, 2006). The development of labor-saving technologies for green manures and other organic methods may help these households and other smallholder farmers overcome labor constraints. On the positive side, when smallholders are able and willing to hire non-family labor, then labor-intensive organic methods can increase local employment opportunities (Halberg et al., 2006). Labor demand associated with ecological farming may be more continuous than the peak season demand associated with conventional farming.

Risk and Time Preferences

The long-term perspective of sustainable agriculture and short-term planning horizon for smallholder farmers can hinder the adoption of ecological farming methods. The environmental benefits associated with ecological farming are explicitly weighted toward the future, but require farmers to bear costs in the current period. As always technologies that demand cash payments will strongly compete with cash needs for other items, such as school fees and medical expenses.

Whether ecological farming requires less cash outlay than conventional methods depends on local conditions. Ecological farmers will spend less than conventional farmers on hybrid seeds and chemical fertilizers and pesticides, but may need to hire additional labor to implement organic methods or purchase non-chemical fertilizers when local biomass sources are scarce (Pender & Mertz, 2006). For both ecological and conventional farming systems, imperfect credit markets and high costs of borrowing can discourage adoption of new practices (Shiferaw et al., 2009).

The long-term benefits of sustainable agricultural will particularly fail to sway farmers who lack secure land tenure or access. Factors such as lack of land title, uncertainty of usufructuary rights, land rental, and the prevalence of land invasions have been shown to decrease the adoption rates of farming practices that deliver benefits in the long-run (Lee, 2005). The land rights of women also impact the implementation of ecological farming techniques. In many parts of SSA, women lack rights to inherit land or make decisions about land management, even though they are often the primary food producers (Pender & Mertz, 2006).

Smallholder farmers are typically risk averse and have difficulty buffering themselves against health, climatic, and socioeconomic shocks. Like any agricultural technique, ecological farming practices may increase risks if implemented poorly or under the wrong conditions. For example, Shiferaw et al. cite evidence from Ethiopia that soil and stone bunds exacerbated flooding problems and caused pest outbreaks.

However, other studies have shown that organic approaches are more resilient than conventional methods during times of drought and pest infestation (Parrott et al., 2006). For example, farmers adopting polyculture and intercropping in Tanzania were able to mitigate the effects of seasonal drought and regulate pest outbreaks (Lin et al., 2008). To the extent that fewer inputs are purchased, organic farming may shield farmers from market risks encountered by having to regularly replace seed, or purchase fertilizer. Empirical evidence shows that when farmers understand the risk-reducing benefits of ecological farming practices, they are more willing to increase expenditures and invest in the practices as a way to buffer against external shocks (Shiferaw et al., 2009). In the face of shifting temperature and rainfall patterns, some believe ecological agriculture techniques have the potential to help smallholder farmers in SSA adapt to climate change (Boko et al., 2007; Lin et al., 2008).

Conclusion

Ecological farming seeks to satisfy food production needs while maintaining and enhancing natural resources and social systems. Observing that constraints such as lack of capital for seeds and fertilizers and poor infrastructure have prevented many SSA smallholder farmers from adopting modern, high-input systems, ecological farming advocates promote organic and LEISA practices as promising alternatives for agricultural development.

As concluded by several authors, choosing the right system for agriculture in SSA requires a pragmatic approach that focuses on what is feasible and profitable for smallholder farmers in diverse biophysical and socioeconomic settings (Pender & Mertz, 2006; Halberg et al., 2006; Shiferaw et al., 2009). Ecological farming may increase yields and productivity relative to traditional methods, but only if farmers have access to an appropriate set of inputs and specific techniques. In areas with labor availability and capacity for participatory research and adaptation of farming practices, ecological agriculture can be an appropriate option for improving food production.

Literature Review Methodology

This literature review was conducted using Google Scholar, Web of Science, and ScienceDirect search engines. In addition, numerous NGO and government websites were searched including the World Bank, FAO, and CGIAR. Search terms included, among others: ecological farming, ecological agriculture, low-input farming, LEISA, LEIA, sustainable farming, and organic farming. Searches that returned numerous results were narrowed to include only papers relevant to Africa published since 2000.

References

Altieri, M. E. (Ed.). (1995). *Agroecology: the science of sustainable agriculture, 2nd ed.* Boulder, CO: Westview.

Ammann, K. (2008). Integrated farming: why organic farmers should use transgenic crops. *New Biotechnology*, *25*(2/3), 101-105.

Badgley et al. (2007). Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems*, *22*(2), 86-108.

Boko, M. I. et al. (2007). Africa. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, & C.E. Hanson (Eds.), Cambridge: University Press, 433-467.

Borlaug, N. E. (2002). Feeding a world of 10 billion people: the miracle ahead. *In Vitro Cellular & Developmental Biology. Plant*, *38*(2), 221-228.

Borlaug, N. E. (2000). Ending world hunger. The promise of biotechnology and the threat of antiscience zealotry. *Plant Physiology*, *124*(2), 487-490.

FAO. (2007). Papers submitted for International Conference on Organic Agriculture and Food Security.

Fernandes, E., Pell, A., & Uphoff, N. (2005). Rethinking agriculture for new opportunities. In J. Pretty (Ed.), *The Earthscan Reader in Sustainable Agriculture* (pp. 321-340). London: Earthscan.

Giller, K. E., Witter, E., Corbeels, M., & Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research*, *114*(2009), 23-34.

Graves, A., Matthews, R., & Waldie, K. (2004). Low external input technologies. In Donald L. Sparks (Ed.), *Advances in Agronomy, Volume 82* (pp. 473-555). New York: Elsevier.

Haggblade, S. & Tembo, G. (2003). Conservation farming in Zambia. Environment and Production Technology Division Discussion Paper No. 108. Washington, DC: International Food Policy Research Institute.

Halberg, N., Sulser, T. B., Hogh-Jensen, H., Rosengrant, M. W., & Knudsen, M. T. (2006). The impact of organic farming on food security in a regional and global perspective. In N. Halberg, H. F. Alroe, M. T. Knudsen, & E. S. Kristensen (Eds.), *Global Development of Organic Agriculture: Challenges and Prospsects* (pp. 277 - 322). Wallingford, UK: CABI Publishing.

Hassanali, A., Herren, H., Khan, Z., Pickett, J., & Woodcock, C. (2008). Integrated pest management: the push–pull approach for controlling insect pests and weeds of cereals, and its potential for other agricultural systems including animal husbandry. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*, 611-621.

Hecht, S. B. (1995). The evolution of agroecological thought. In M. A. Altieri (Ed.), *Agroecology: the science of sustainable agriculture, 2nd ed.* (pp. 1-19). Boulder, CO: Westview.

IFOAM (2007). Final draft on the definition of organic agriculture. http://www.ifoam.org/growing_organic/definitions/sdhw/pdf/Final_Draft_Definition_of_Organic_Agriculture.pdf. Accessed 22 Oct. 2009.

Kuyvenhover, A., & Ruben, R. (2002). Conditions for sustainable agricultural intensification. In N. T. Uphoff (Ed.), *Agroecological innovations: increasing food production with participatory development* (pp. 58-70). London: Earthscan Publications.

Lee, D. R. (2005). Agricultural sustainability and technology adoption: issues and policies for developing countries. *American Journal of Agricultural Economics*, (87)5, 1325-1334.

Lin, B. B., Perfect, I., & Vandermeer, J. (2008). Synergies between agricultural intensification and climate change could create surprising vulnerabilities for crops. *BioScience*, 58(9), 847-854.

McDonald, A.J., Hobbs, & P.R., Riha, S.J. (2008) Stubborn facts: Still no evidence that the System of Rice Intensification out-yields best management practices (BMPs) beyond Madagascar. *Field Crops Research*, 108(2008), 188-191.

McNelly, J. A., & Scherr, Sara J. (2003). *Ecoagriculture: Strategies to Feed the World and Save Wild Biodiversity*. Washington, DC: Island Press.

Mercer, D. E. (2004). Adoption of agroforestry innovations in the tropics: A review. *Agroforestry Systems*, 204411, 311-328.

Nandwa, S. M., & Bekunda, M. A. (1998). Research on nutrient flows and balances in East and Southern Africa: state of the art. *Agriculture, Ecosystems and Environment*, 71, 5-18.

Parrott, N., Olesen, J. E., & Hogh-Jensen, H. (2006). Certified and non-certified organic farming in the developing world. In N. Halberg, H. F. Alroe, M. T. Knudsen, & E. S. Kristensen (Eds.), *Global Development of Organic Agriculture: Challenges and Prospsects* (pp. 154-179). Wallingford, UK: CABI Publishing.

Pender, J., & Mertz, O. (2006). Soil fertility depletion in sub-Saharan Africa: what is the role of organic agriculture? In N. Halberg, H. F. Alroe, M. T. Knudsen, & E. S. Kristensen (Eds.), *Global Development of Organic Agriculture: Challenges and Prospsects* (pp. 215-240). Wallingford, UK: CABI Publishing.

Phalan, B., Rodrigues, A., & Balmford, A. (2007). Comment on "Resource conserving agriculture increases yields in developing countries." *Environmental Science & Technology*, 41(3), 1054-1055.

Pretty, J. (2008). Agricultural sustainability: concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363, 447-465.

Pretty, J. et al. (2007). Response to comment on "Resource-conserving agriculture increases yields in developing countries." *Environmental Science & Technology*, 41(3), 1056-1057.

Pretty, J. et al. (2006). Resource-conserving agriculture increases yields in developing countries. *Environmental Science & Technology*, 40(4), 1114-1119.

Pretty, J., Morison, J., & Hine, R. (2003). Reducing food poverty by increasing agricultural sustainability in developing countries. *Agriculture, Ecosystems and Environment*, 95, 217-234.

Pretty, J., & Hine, R. (2001). Reducing food poverty with sustainable agriculture: a summary of new evidence. SAFE-World Research Project. Colchester: University of Essex Press.

Pretty, J. (1999). Can sustainable agriculture feed Africa? New evidence on progress, processes and impacts. *Environment, Development and Sustainability*, 1, 253-274.

Reijntjes, C., Haverkort, B., & Waters-Bayer, A. (1992). *Farming for the Future: An Introduction to Low External Input and Sustainable Agriculture*. Leusden, NL: Macmillian/ILEIA.

Rigby, D., & Caceres, D. (2001). Organic farming and the sustainability of agricultural systems. *Agricultural Systems*, 68, 21-40.

Schlecht, E., Buerkert, A., Tielkes, E., & Bationo, A. (2006). A critical analysis of challenges and opportunities for soil fertility restoration in Sudano-Sahelian West Africa. *Nutrient Cycling in Agroecosystems*, 76, 109-136.

Shiferaw, B. A., Okello, J., & Reddy, R. V. (2009). Adoption and adaptation of natural resource management innovations in smallholder agriculture: reflections on key lessons and best practices. *Environment, Development and Sustainability*, 11(3), 601-619.

United Nations Environment Programme-United Nations Conference on Trade and Development Capacity Building Task Force on Trade, Environment and Development. (2008). Organic agriculture and food security in Africa.