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The Potent Reliant of Agro-ecological Farming: A Review

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ABSTRACT Agro-ecological farming and conventional farming are two methods to food production. The word 'agro-ecological farming' refers to a diversity of agricultural methods that seek to provide food by using available natural and local resources rather than off-farm inputs that is sustainable, socially and environmentally acceptable. Recent debate about the advantages of agro-ecological farming over conventional systems has centred on each method's capability to increase output in the background of several and diverse biophysical and social limitations. An appraisal of the literature suggests that agro-ecological farming can offer some benefits to small-scale farmers, but that precise methods must be tailored to soil-climatic conditions, local climate, labour availability, training as well as organic inputs availability.

INTRODUCTION

According to Silici (2014) and Chable et al. (2020), there is no standardised description of agro-ecological farming or conventional farming. Killebrew et al. (2009) argue that most scholars differentiate the techniques centred on different procedures, methods, inputs and aims. On the other hand, conventional farming involves the use of modern technologies, and inorganic external inputs like high-yielding seed varieties, heavy mechanisation, chemical fertilisers and pesticides (Pretty and Bharucha 2014). Killebrew et al. (2009) further argue that conventional farming centres on handling problems within the crop field, such as soil nutrients, and pest outbreaks, with the principal aim being to increase produce and production. Hecht (1995) terms this technique as a target approach, because its purpose to the farming system is mainly on production. Approaches related with conventional agriculture include use of genetically modified seed, mono-cropping, use of artificial fertilisers and pesticides, and use of heavy machines such as tractors (Oliver 2014; Devkota et al. 2020).

Agro-ecological farming is a wide description for agricultural techniques that seek to be more viable than conventional agriculture by avoiding undesirable materials that are not beneficial to the social environment (Pretty and Bharucha 2014; Brzozowski and Mazourek 2018; Fiebrig et al. 2020). It is important to note that the concept of time is fundamental to agro-ecological farming's description. However, in response to conventional farming's inferred focus being on the current period, agro-ecological takes a long-term outlook (Killebrew et al. 2009). Using renewable resources in a manner that does not diminish them, agro-ecological farming aims to sustain productivity and the general well-being of the society in particular (Pretty 2008; Magrini et al. 2019). For instance, Rigby and Caceres (2001) and Gomiero et al. (2011) have questioned the long-run sustainability of conventional agriculture practices, like the use of man-made materials and reliance on genetically based materials for productivity.

Agro-ecological farming consists of several systems and procedures, with the purpose of achieving only one goal (that is the lessening and exclusion of non-renewable inputs) (Kremen et al. 2012; Vaarst et al. 2018). Pretty and Bharucha (2014) argue that chemical pesticides and fertilisers are prohibited in agro-ecological farming, and instead natural processes and locally available resources to support crop growth are utilised. The methods used in agro-ecological farming are generally wide-ranging and background-precise and may include terracing and minimum or zero tillage for soil management, mulching, intercropping for pest and weed management, crop rotation for soil fertility, cover crops, rainfed methods and drip irrigation for water harvesting and delivery (Lee 2005; Shiferaw et al. 2009; Zhu et al. 2011; Kumar et al. 2019). It is therefore imperative to note that agro-ecological farming methods are centred on both traditional and scientific knowledge.

Agro-ecological farming widens conventional farming's approach on food production to also include social and environmental upshots (Killebrew et al. 2009; Gliessman et al. 2019; Sinclair et al. 2019). This involves using natural practices to replace off-farm inputs, with the aim of improving soil conditions, reducing energy loss, boosting natural interactions of microorganisms as well as enhancement of the biomass. Pretty (2008) and Gliessman et al. (2019) posit that sustainable farming encourages new social conformations based around management skills, leadership, trust, and the capability to innovate. However, the method used is said to be holistic rather than targeted merely on production (UNEP-UNCTAD 2008).

Killebrew et al. (2009) summarised the method used in agro-ecological and conventional farming regarding the mode of production, practices, distinctive inputs and their goals as:

1. Agro-ecological farming involves a holistic approach while conventional farming is a target approach;
2. Crop rotation, cover crops, mulching, intercropping, minimum tillage, polycropping, construction of rainfed or drip irrigation systems, use of natural parasitic relationships are key to agro-ecological farming while conventional farming entails the use of chemical and pesticides, monocropping, use of genetically modified seeds, and construction of irrigation systems;
3. Education and training in agro-ecological farming practices, intensive labour, manure accessibility or other organic, implementation of practices to local background are distinctive inputs in agro-ecological farming while and financial access to mineral, artificial pesticides, and improved crop varieties, irrigation sources or adequate rainfall are key to conventional farming; and
4. Agro-ecological farming aims to maintain and improve food production, environmental conditions, and social well-being of the people while conventional farming goal is to increase yields and productivity.

An assertion commonly made between agro-ecological and conventional agriculture is that the former involves a net decrease in input use (Altieri and Nicholls 2005). Pretty (2008) noted that agro-ecological farming alters, rather than decreases the production factors, from fertilisers and herbicides to nitrogen-fixing cover crops. Whereas, Pender and Mertz (2006) advance that to thrive, agro-ecological farming demands intensive involvements in the form of training and indigenous adaptation of techniques, labour and natural manure. However, Halberg et al. (2006) and Altieri (2015) described agro-ecological systems as 'knowledge intensive' rather than 'input intensive', necessitating that farmers have current knowledge or acquired training in handling integrated systems.

Parrott et al. (2006) highlighted that farming methods categorised by a lack of off-farm inputs are not agro-ecological or organic by default. Parrott et al. (2006) further added that resource-poor farmers who farm without the use of biochemical inputs often do so out of poverty and inadequacy of resources, and not due to a mindful choice to practice an incorporated agro-ecological method.

Quite a number of terms are used to describe agro-ecological farming, which may include low external inputs sustainable agriculture [LEISA], sustainable agriculture, limited external input agriculture [LEIA], and organic farming (Pender and Mertz 2006; Pretty 2008; Oberè and Arroyo Schnell 2020). However, there is no comprehensively acknowledged nomenclature for agro-ecological farming methods (Wezel et al. 2018), with some authors (for instance, Pender and Mertz 2006; FAO 2007; Ibeawuchi et al. 2015) describing organic farming as a form of low external input viable farming and vice-versa.

Sustainable Agriculture

This is a form of agro-ecological farming that makes the best use of renewable resources with little or no effect on the environment, social and human assets (Pretty et al. 2008; Oberè and Arroyo Schnell 2020). According to Lee (2005) and Kelly (2009), sustainable methods are usually considered to use a lesser amount of external off-farm inputs and employ better management approaches. Further to this, they use locally available natural resources and purchased inputs in a resourceful, and complementary manner.

Low External Input Sustainable Agriculture (LEISA) and Limited External Inputs Agriculture (LEIA)

These involve limited or no use of external inputs like pesticides, fertilisers, and genetically modified seeds (Killebrew et al. 2009). The agro-ecological ideologies surrounding these methods include, promoting nutrient availability through biological nitrogen fixation, nutrient recycling, and partial complementary use of artificial manures. Other methods comprise of reducing soil losses by managing micro-climates and water, minimising pest and disease infestations, and providing favourable soil condition for plant growth through efficient soil organic management and improving soil organic activity (Reijntjes et al. 1992; Tripp 2006; Lampkin et al. 2015). Reijntjes et al. (1992) in their research highlighted that the major difference between LEISA and organic farming is that LEISA permits safe and effective use of external inputs. However, Parrott et al. (2006) argued that the two methods are very similar in practice.

Organic Farming

This is also one of the methods of agro-ecological farming. The method of production involves biological, cultural, and mechanical methods of producing food rather than inputs that are detrimental to the environment (IFOAM 2007). Organic agriculture encompasses both certified and non-certified organic agriculture. It is imperative to note that the WHO Codex Alimentarius proposed guidelines define international principles for certified organic farming. However, non-certified organic agriculture farmers trail the same ideologies set out by the International Federation of Organic Agricultural Movements (IFOAM) but do not have their products certified. This might be because these farmers are resource poor and are financially constrained to purchase a licence as a certified farmer.

METHODOLOGY

The purpose of this paper is to present a systematic review of literature based on the potent reliant of agro-ecological farming as a sustainable farming system. To realise this, appropriate research papers were reviewed after gathering, assessing, and integrating data from an outsized number of sources. The appraisal was actualised systematically using distinct peer-reviewed and non-peer reviewed papers, books and authorised publications. The basic short phrase used was agro-ecology farming and its various approaches to sustainable farming. The terminology was joined with yield efficiency, local environments, management capacity, biodiversity, resilience, and transitions between systems. The aforementioned terms were used in order to find related research both in developed and developing countries. Publications that are not in English language and those that were not inline with the phenomenon of the study where deemed as unreliable, and hence, excluded.

Assessment of Agro-ecological Farming in Africa

Yield Efficiency

A debated question that is often being raised is the degree to which agro-ecological farming systems can increase agricultural production to feed Africa and the rest of the world (Killebrew et al. 2009). Non-promoters of agro-ecological farming claim that lessening the use of artificial fertilisers and pesticides may limit the production of food and require the transformation of millions hectares of natural habitat into farmland (Borlaug 2002). However, promoters of agro-ecological farming (for instance, UNEP-UNCTAD 2008) suggest that conventional systems are unsuited with the conditions confronting most sub-Saharan Africa farmers and that current studies reveal the prospective for agro-ecological farming to increase food production in most developing nations.

Meta-analyses Studies on Yields

Meta-analyses of several hundred farming cases was carried out by Pretty et al. (2006) and

Badgley et al. (2007) to evaluate the effect on yields of implementing agro-ecological farming methods. Pretty et al. (2006) examined yields from 286 viable agriculture schemes in 57 developing nations including Sub-Saharan Africa, Middle East and North Africa, Europe and Central Asia, South Asia, East Asia and Pacific, and Latin America and Caribbean. The research sampled agricultural projects indicating all eight groups of Food and Agriculture Organisation (FAO) farm methods. The study evaluated yield variations using two procedures. Firstly, sampling some sites once to measure yield variances between plots with and without ecological methods, and secondly, sampling some sites twice over a period of 4 years to make before and after contrasts. However, the study did not explain how long sustainable approaches had been in place when experimentation took place.

The results of the sampled data show that an increase of about seventy-five percent on crop yields was noted on average due to effective transformation from traditional (unimproved) farming systems to sustainable management practices. Crops such as coffee, potato, fruits, and cassava/sweet potato demonstrated the largest yield increases while soybeans, cotton, groundnuts, and rice made the smallest yield increases. The samples of the study comprised farms that adopted a diverse range of agro-ecological methods, ranging from minimum/zero tillage and agroforestry to integrated pest management and intercropping approaches. However, Pretty et al. (2006) hypothesised that increasing yields in a sustainable manner involves three kinds of fundamental practical improvement such as, (i) more effective water use both in dry-land and irrigated farming, (ii) improvements in organic material accumulation in soils and carbon sequestration, and (iii) pest, weed, and disease control underlining in-field biodiversity and reduced pesticides use. A similar observation on studies conducted by Pretty and Hine in 2001 and Pretty et al. in 2003 also found increased yield following the introduction of eco-friendly sensitive approaches to traditional farming methods.

Furthermore, Badgley et al. (2007) also noted an increase in food production in a study that assessed the prospective contribution of organic farming to the universal food supply by calculating relative yields between organic and conventional systems. However, the research team compiled 293 published cases that compare yields from organic methods to methods using locally prevalent systems in both developed and developing nations. For developing nations, locally prevalent approaches largely involved non-intensive, traditional farming methods. In their findings, an average yield ratio that was slightly greater than 1.0 for developing nations was observed, meaning organic yield was one hundred percent that of the yield from locally prevalent methods. It is therefore, important to note that putting all management practices into consideration, small-scale farmers in most developing nations can thrive using locally available resources for their production.

Studies on Yield over Time

Studies centring on precise agro-ecological farming approaches, like agroforestry and conservative agriculture, highlight the significance of exploratory yield effects over time (Killebrew et al. 2009). Shiferaw (2009) noted that most agro-ecological farming practices are time-consuming than conventional systems in terms of improving food production. For instance, farmers who adopting agroforestry may need to wait for about 3 to 6 years before achieving the overall benefits of the system. The difficulty of agroforestry and other unified methods means that farmers basically need more time to test and implement new inputs and methods as compared to conventional approaches (Mercer 2004; Sagastuy and Krause 2019).

Notwithstanding, biophysical conditions such as climate, soil condition may also be a factor that can contribute to delay of yield developments from agro-ecological farming. Giller et al. (2009) reviewed yield data from farms implementing conservation agriculture in sub-Saharan Africa and reported no yield benefits, and in some cases, reduced yield in the short-term but over longer periods say from 6 to 10 years. Findings further revealed that, yield responses were neutral to positive, as conservation agriculture slowly arrested soil dilapidation and increased soil micronutrients.

The extant literature also indicates that, the time needed to realise the benefits from agro-ecological farming may serve as a hindrance to implementation (Killebrew et al. 2009). Farming techniques that result in revenues to decline in the short-term are unlikely to be implemented, even if implementation may enhance future income to an extent that it can compensate for initial losses. Shiferaw (2009) argued that losses could only be compensated only if subsidies are made available, because a majority of the resource poor farmers cannot afford temporal income trade-offs.

In the long run, agro-ecological farming techniques may uphold yields more efficiently than conventional techniques. For instance, high yielding seed varieties have generated intense maize yield upsurges in several SSA countries. The use of fertiliser, however, has trailed behind the use of high yielding seeds. Therefore, such stepwise technology implementation can result in the depletion of soil fertility, since high yielding seeds absorb soil nutrients more speedily than traditional seeds.

The combination of both degraded soils and the use of heavy chemical fertiliser can also decrease yields over a period of time (Killebrew et al. 2009). Land dilapidation procedures, like loss of soil organic nutrient and topsoil, reduce the effectiveness of artificial fertiliser inputs (Pender and Mertz 2006). Killebrew et al. (2009) noted that in a long-term experiment in Kenya, maize yields declined by fifty percent during a seven-year period under non-stop cropping with chemical fertiliser. Nandwa and Bekunda (1998) argued that farmyard manure produced higher yields that declined less over time.

However, in parts of SSA with prevailing soil deficiencies, organic farming approaches may prove unachievable in the long-run due to soils that are phosphorus fixing or phosphorus and potassium lacking, which may entail processed or chemical fertiliser to sustain production (Killebrew et al. 2009). Use of unprocessed phosphate rock is an organic alternative for some areas, but phosphate rock deposits are spotted in SSA, and outside West Africa, and unrefined phosphate lacks the reactivity required to be useable for soil fertility replenishment (Pender and Mertz 2006).

The question relating to whether agro-ecological farming techniques will enhance or reduce food production relies on the general starting conditions of the farming system (Silici 2014). Because a majority of the SSA small-scale farmers usually start from conditions of degraded soils and inadequate access to modern inputs. Therefore, agro-ecological farming methods have the prospective to increase yields, as would lower cost access to more external inputs.

Suitability for Local Environments

Another line of research examines whether agro-ecological farming is more appropriate than conventional farming to SSA's biophysical and socio-economic conditions. Promoters of agro-ecological farming (for instance, Altieri 1995; Otsuka and Muraoka 2017) argued that Green Revolution technology is unsuited with SSA farmers that are resource constrained. This type of argument focuses on the aspects that make small-scale farmers more or less likely to implement agricultural practices rather than debating about yield and productivity.

Lee (2005) and Shiferaw et al. (2009) provided conceptual frameworks for small-scale implementation of agro-ecological management practices and evaluated proof of the concepts working in practices. However, the two studies start from the standpoint that agro-ecological techniques have the prospective to increase food production in a manner that is environmentally friendly, but that the challenges and opportunities for extensive implementation need to be better understood.

Training, Research and Management Capacity Essentialities

A major challenge for extensive diffusion of agro-ecological farming is the site precise nature of LEISA and organic methods (Lee 2005). Sustainable farming, by description, seeks to make the best likely use of natural processes and indigenous knowledge and skills (Pretty 2008). Killebrew et al. (2009) argued that to make efficient use of natural processes, all agro-ecological methods must be fitted to place, taking into account factors such as, local agro-climatic conditions, availability of resources, and human population conditions.

Looking at the heterogeneity of biophysical and social state of affairs in SSA, promoters of agro-ecological farming contend that a modified method is more suited than conventional farming of a one size-fits-all system. However, Lee (2005) noted some examples from SSA of agro-ecological farming methods effectively, addressing location-specific limitations and or scarcity of resources. For instance, in Southwest Cameroon, farmers adopted the use of alley cropping methods rather than conventional bush fallow rotations to overcome fuel and wood inadequacy. Similarly, in some parts of East Africa, farmers have used leguminous fallow practices to address the extensive gradual depletion of soil fertility in the area.

It is therefore, imperative to note that the prospective of agro-ecological techniques to address location-specific limitations will rest upon the farmers' education level and management capability as well as availability of extension services. To implement sustainable farming methods and practice them to local conditions, farmers must have acquired or be receiving training in observational, logical, experimental, and communications skills (Killebrew et al. 2009). Halberg et al. (2006) further advances that farmers without such training may be incompetent to appropriately manage the complex associations of biological processes as such, they tend to give up when the results predicted by experts fail to materialise. Extension services and training have proved to be more significant in adopting sustainable farming methods. For example, Lee (2005) found evidence involving farmers-based organisations, non-governmental organisations, extension services, and outreach programs that provided information and training to farmers led to significant increases and effective implementation of agro-ecological agricultural practices.

Such practices with their natural resource handling operations include: 1) agroforestry methods/mulching, 2) leguminous plant intercropping/cover crops and green manures, 3) organic farming/soil aeration, 4) introduction to better-quality crop multiplicities/weed management, 5) rotational cropping, including grain-legumes cycles/soil fertility handling, 6) inter-cropping and poly-culture (mixed, row, strip, relay)/ drip irrigation, 7) alley farming/better-quality drainage system, 8) improved use and effectiveness of animal manure/precision farming, 9) rain-water harvesting and storage, micro and macro-basins/raised beds, raised fields, 10) hedgerows and live barriers/contour farming, 11) minimum tillage, zero tillage, deep tillage, reduced tillage/ windbreaks, 12) better forage and grazing handling/improved agrosilvopastoral methods, 13) grass strips and trash lines/terraces, 14) ditches/stone and soil bunds, 15) interrelated of man-made/organic/crop diversification and high-value crops, 16) better effectiveness in use of irrigation water/seed preservation and local seed banks, 17) aquaculture and unified crop-aquaculture methods/home gardens, and 18) method of rice intensification/ modifying crop compactness and architecture (Lee 2005).

Shiferaw et al. (2009) highlighted the importance of involving farmers in the selection and implementation of appropriate approaches. Shiferaw et al. (2009) further added that bottom-up participatory techniques give farmers a chance to test and implement several practices at their own pace and adjust approaches according to changing conditions. Shiferaw et al. (2009) concluded that the capability of agro-ecological farming to overcome local limitations rest on the availability of education and training about selecting and adopting agro-ecological practices.

Labour Essentialities

The role of labour in agro-ecological farming adoption is crucial. Lee (2005) and Shiferaw et al. (2009) observed that the availability of labour influences the implementation of agro-ecological farming methods, which are usually more labour intensive than conventional systems. For example, making of compost, tree planting, mulching, rainwater harvesting, and applying household waste and farmyard fertiliser have high labour requirements (Parrott et al. 2006; Schlecht et al. 2006). Pender and Mertz (2006) noted putting fertiliser on one hectare of maize with 100 kilograms of nitrogen, a farmer would need to apply more 20 tonnes of leaf biomass or manure, compared to only 217 kilograms of urea.

Meanwhile, factors such as availability of family labour, household size, access to labour market, and the opportunity costs of labour may intensely influence the possibility of implementing agro-ecological management practices. Empirical evidence shows that households endowed with more family labour will have an advantage in adopting labour-intensive practices (Shiferaw et al. 2009). Lee (2005) argues that increased off-farm and non-farm labour opportunities permit households to generate the liquidity required for investments in new agro-ecological farming knowledge while, on the other hand, this may concurrently lessen the likelihood of implementing labour-intensive agro-ecological practices. However, on the positive side, when small-scale farmers are able and willing to employ non-family labour, then labour-intensive organic approaches can increase local employment prospects (Halberg et al. 2006).

Agro-ecology for Maintaining, Improving and Utilizing Biological Diversity

This type of farming practices relies on ecological unit services rather than off-farm inputs (Wezel et al. 2014; Isgren 2016). The farming practices consider biological diversity and ecological procedures to be at the heart of the agroecosystem effectiveness (Schoonhoven and Runhaar 2018), through the establishment of ecosystem services, and have great prospective for developing innovative as well as viable agricultural production approaches (Bretagnolle et al. 2018). One of the primary aims of agroecological farming is to lessen environmental impacts of agriculture with the purpose of meeting the rising demand for food, contributing to landscape quality and biodiversity (Schoonhoven and Runhaar 2018), and improving resilience (Therond et al. 2017). Agro-ecology is used both as an overall farming concept (Sherwood and Uphoff 2000; Díaz et al. 2006; Schoonhoven and Runhaar 2018) and as an approach to combat specific problems associated with farming, such as land dilapidation (Pearson 2007).

Studies have shown that at least in the short run, yields from agro-ecological farming are lower than that of conventional farming (Schoonhoven and Runhaar 2018), although there are also studies that have reported equal yields of the two systems (Erisman et al. 2016). (Schoonhoven and Runhaar 2018) further added that yields from agro-ecology could generate more stable farmer income due to more resilient soils and farming systems. However, as other studies conclude differently on whether agro-ecology is an appropriate measure that can improve farmer's livelihoods (Thorn et al. 2016). This implies that there is a need for more research on the effect of agro-ecology of farmers' livelihoods.

In the operationalisation of agro-ecology into specific measures and farming practices, the concept bears resemblance, and also to some extent overlaps with concepts such as sustainable agriculture, sustainable intensification, conversation agriculture, ecological agriculture, carbon farming and resilient agriculture (Govaerts et al. 2009; Erisman et al. 2016; Therond et al. 2017; Schoonhoven and Runhaar 2018). Schoonhoven and Runhaar (2018) added that some shared measures and themes include elements such as minimum tillage, natural pest control, efficient irrigation and crop rotation. The operationalisation of agro-ecological ideologies to farming practices depends on the type of farming activity involved (for example, crop farming or dairy farming), climate conditions, socio-economic contexts, soil characteristics, intensity of farming (Therond et al. 2017).

To a certain degree these methods can re-establish "field and landscape-scale" connectivity and diversity, and they may also contribute substantially to conserving and re-establishing wildlife habitat and ecosystem services in agriculture-prevailed terrains.

Flexibility and Incorporation of Production Systems

The problems faced in the 21st century are complex by the fact that what is required is not one approach but several approaches of viable magnification (and in some circumstances de-intensification), which are centred on a broad array of methods that are suitable to an outsized quantity of precise agro-ecological and socio-economic backgrounds (Pretty et al. 2010). To overcome these problems, incorporation (or additional precise reincorporation) of production methods offers both considerable problems and prospects for agro-ecology. Incorporated cropping and mixed-methods alternatives at the field and farm scale are basics of the agro-ecological literature that are uncultivated cycles, permaculture, crop-livestock methods, cover crops, agroforestry, and even crop-livestock aquaculture methods (Tomich et al. 2011). Quite a number of these agro-ecological methods hold specific prospects as fundamentals of unified nutrient handling approaches (Kramer et al. 2006). Kramer et al. (2006) further added that these methods can re-establish field and landscape-scale interconnection and diversity, which as well may contribute extensively to conserving and restoring wildlife habitat and ecological system services in agriculture-prevailed terrains. It is therefore important to note that agro-ecology improves the adaptive capability of agro-ecosystems and lessens susceptibility to natural catastrophes, climate variability impacts, and new and evolving environmental and economic system stresses and shocks. For example, Holt-Giménez (2002) noted that the use agro-ecological methods by small-scale farmers to resist the unfavourable consequences of Hurricane Mitch in Nicaragua proved to be effective. In the aftermath of the hurricane, agro-ecologically managed plots in Nicaragua retained more topsoil, field moisture and vegetation, and suffered less erosion than conventionally managed resource-extractive farms. The emerging result from this research revealed that this resilience was accomplished by ways of physical and biological means with respect to habitat and crop diversification, and increased carbon sequestration. Some of the other variables included location-based conservation of local/indigenous seed and germplasm diversity, improved water capture and retention as well as preservation of natural enemies' species diversity (Ghersa 2012).

As an applied science, agro-ecology practices are well known for entrenched eco-friendly ideologies for the method and regulation of diversified agro-ecosystems where off-farm inputs are substituted by natural procedures such as biological control, natural soil richness and allelopathy (Altieri 1995; Gliessman 1998). The various agro-ecological ideologies for the design of bio-diverse, energy efficient, resource-conversing and resilient farming systems aim to; 1) improve the reprocessing of biomass, with a view to optimizing organic material putrefaction and nutrient cycling over time, 2) reduce losses of mineral nutrients, energy, water and genetic resources by improving preservation and restoration of soil and water resources and agro-biodiversity, 3) offer the most favourable soil conditions for plant development, particularly by managing organic matter and by boosting soil biological activity, 4) sustain the immune system of agricultural methods for improvement of effective biodiversity-natural enemies, by generating relevant habitats, 5) improve diversity of species and genetic resources in the agro-ecosystem over time and space at the field and landscape level, and 6) improve advantageous organic relations and synergies amongst the essential parts of agro-biodiversity, thus supporting fundamental ecological methods and services (Altieri 1995; Gliessman 1998). It is imperative to note that agro-ecology does not support technical recipes but rather the above mentioned ideologies, which when applied in a particular region take different technological procedures depending on the prevailing socio-economic and bio-physical conditions of farmers (Altieri 1995; Gliessman 1998).

The summary of Altieri (1995) and Gliessman (1998) shows the differences of agro-ecology resilience and integration of production systems, and the approaches used in attaining a sustainable production system. The management practices employed contribute differently to each principle, thus making the system more sustainable, eco-friendly than the conventional system. However, this depends on how it is distinctly applied and complemented or not by other practices, in a way that one particular practice can sometimes act as an ecological turntable by activating several processes such as allelopathy, biological control and nutrient cycling, which is all important for the healthiness and efficiency of a farming system (Nicholls et al. 2016). For instance, the use of cover crops as indicated by Altieri (1995) can display some numerous outcomes concurrently including repression of unwanted plant, soil-borne diseases and pests, safeguard the soil from rain and runoff, boost soil overall firmness, add effective organic material, fix nitrogen and search for nutrients. In essence, each production method depicts a discrete category of management handling and by inference, ecological relations (Nicholls et al. 2016). This re-affirms the fact that agro-ecological structures are site specific and what may be appropriate in another place are not the procedures but rather the ecological ethics that bring about viability.

Agricultural Inputs, Farming Practices and Transitions between Systems

The National Research Council (2010) compares a transformative strategy to agricultural sustainability that applies a wider system of viewpoints similar to this review with an incremental method that entails comparatively small changes in practices within prevailing production systems (for instance, the gradual replacement of integrated pest management [IPM] and cover crops for inputs derived from petroleum and natural gas). In a wider background, the scientific debate about whether organic farming can meet growing universal food needs remains unresolved (Tomich et al. 2011). Variances in appraisals of practicability of meeting crop N prerequisites by way of biological N fixation, composting, cover crops, manure, and crop rotations are the central point of this disagreement (Badgley et al. 2007; Cassman 2007; Kirchmann and Bergstrom 2008). However, much more needs to be known about the dynamics and nutrient-use efficacy of various kinds of fertilisers used individually and also for combinations of organic and synthetic fertilisers, and nowhere is this more important than for farming systems in sub-Saharan Africa (Chivenge et al. 2011; Vanlauwe et al. 2011).

Several authors have conceptualised agro-ecosystem transformation as a transitional procedure with three distinct stages (MacRae et al. 1990). These stages are, improved effectiveness of input use through unified pest management or unified soil richness management, input replacement using eco-friendly inputs (such as botanical or microbial pesticides, and bio-fertilisers), and a system restructure or distribution through optimum crop/animal assemblages, which stimulate interconnections that permit the agro-ecosystem to support its own soil richness, crop productivity, and natural pest control. However, most of the practices that are being presently promoted as parts of viable farming fall in 'categories 1 and 2'.

Nicholls et al. (2016) argued that both stages decrease agro-chemical input use and offer advantageousness in terms of lower environmental impacts as well as cost-effective benefits by decreasing costs of production. The fine-turning of inputs use through procedures such as IPM or Integrated Soil Fertility management (ISFM) does little to transition farmers towards a substitute system independent from external inputs (Nicholls et al. 2016). In most cases IPM translates to intelligent pesticide management, highlighting the selective use of pesticides according to a pre-established economics threshold, which pests often surpass in monoculture circumstances. Input replacement used by a majority of organic farmers follows the same paradigm of conventional farming by trying to overcome the limiting factor with biological or organic inputs. However, most of these alternative inputs have been commoditised, thus farmers are still reliant on input suppliers (Rosset and Altieri 1997). For example, in California many organic farmers cultivating strawberries and grapes apply between 12-18 different kinds of biological inputs per season. In addition to improving production costs, as many products are used for one purpose, it affects other facets of the system. A good example is Sulphur, which is broadly used to control foliar diseases of grapes, can also wipe out populations of Anagrus parasitic wasps, key regulators of leafhopper pests. Thus farmers become trapped in an organic treadmill (Nicholls et al. 2016).

Gliessman (2014) argues that improvement in efficacy of inputs use and input replacement are not sufficient to address the challenges confronting contemporary farming. Gliessman (2014) further argues that farming methods must be restructured centred on new ecological interactions. This requires an ecological transition of agriculture centred on ideas of agro-ecology and viability. Thus, system transition arises from the implementation of agro-ecological ideologies that lead to the transformation of the arrangement and function of agro-ecosystems by supporting management guided to establish the following procedures as proposed by Altieri and Nicholls (2012), which are:

1. Improving above and below ground biological diversity
2. Boosting biomass production and soil mineral matter content
3. Effective use of soil nutrients, water, solar energy, seed, soil organisms, pollinators and natural enemies
4. Optimum arrangement of plant-animal cycles and combinations

5. Improvement of efficient complementarities and interconnections between soil, crop and biotic components.

Ultimately, the agro-ecology system's dependence lies in the formation of an ecological arrangement that through plot to landscape-scale diversification, promotes ecological relations that give rise to water storage, soil richness, pest/disease regulation, nutrient cycling and retention, pollination, and other vital ecosystem services (Altieri 2002).

CONCLUSION

In general, agro-ecological farming has proved to be more reliant on satisfying food production essentials while conserving and improving natural resources and social systems. Lack of capital to buy farm inputs such as seeds and fertilisers have prevented a majority of the SSA small-scale farmers from implementing modern, high-inputs techniques, agro-ecological farming proponents promote organic and LEISA practices as promising options for agricultural development.

As indicated by several authors, choosing the right method for agriculture in SSA entails a practical technique that centres on what is realistic and profitable for small-scale farmers in different biophysical and socio-economic settings. Agro-ecological farming may increase yields and production in relation to traditional approaches, but only if farmers have access to right set of inputs and precise methods. However, in areas with labour availability and capability for participatory research and implementation of farming practices, agro-ecological farming can be a suitable alternative for improving food production. Combating specific problems associated with farming such as land dilapidation can also be addressed with proper agro-ecology farming management practices, only if farmers follow the basic management practices in maintaining and improving soil fertility. Integrated cropping and mixed systems with respect to the use of crop rotations, cover crops, agroforestry, permaculture, crop-livestock systems and even crop-livestock aquaculture systems form the basis of agro-ecology farming practices.

REFERENCES

Altieri MA 1995. *Agroecology: The Science of Sustainable Agriculture*. Boulder: Westview Press Inc.

Altieri MA 2002. Agroecology: The science of natural resource management for poor farmers in marginal environments. *Agriculture, Ecosystems and Environment,* 93(1-3): 1-24.

Altieri MA, Nicholls CI 2005. Agroecology and the Search for a Truly Sustainable Agriculture. United Nations Environmental Programme, Environmental Training Network for Latin America and the Caribbean. From <http://www.agroeco.org/doc/agroecology-engl-PNUMA.pdf> (Retrieved on 26 June 2020).

Altieri MA, Nicholls CI 2012. Agroecology: Scaling up for food sovereignty and resiliency. *Sustainable Agriculture Reviews,* 11: 1-29.

Altieri M 2015. *Agroecology, Key Concepts, Principles and Practices. Third World Network (TWN)-SOCLA*. Penang, Malaysia: Jutaprint.

Badgley C, Moghtader J, Quintero E, Zakem E, Chappell MJ, Aviles-Vazquez K, Samulon A, Perfecto I 2007. Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems*, 22(2): 86-108.

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

Bretagnolle V, Berthet E, Gross N, Gauffre B, Plumejeaud C, Houte S, Badenhausser I, Monceau K, Allier F, Monestiez P, Gaba S 2018. Towards sustainable and multifunctional agriculture in farmland landscapes: Lessons from the integrative approach of a French LTSER platform. *Science of the Total Environment*, 627: 822-834.

Brzozowski L, Mazourek M 2018. A sustainable agricultural future relies on the transition to organic agroecological pest management. *Sustainability*, 10(6): 2023.

Cassman KG 2007. Editorial response by Kenneth Cassman: Can organic agriculture feed the world- science to the rescue? *Renewable Agriculture and Food Systems*, 22(2): 83-84.

Chable V, Nuijten E, Costanzo A, Goldringer I, Bocci R, Oehen B, Rey F, Fasoula D, Feher J, Keskitalo M, Koller B 2020. Embedding cultivated diversity in society for agro-ecological transition. *Sustainability*, 12(3): 784.

Chivenge P, Vanlauwe B, Six J 2011. Does the combined application of organic and mineral nutrient sources influence maize productivity? A meta-analysis. *Plant and Soil*, 342(1-2): 1-30.

Devkota R, Pant LP, Gartaula HN, Patel K, Gauchan D, Hambly-Odame H, Thapa B, Raizada MN 2020. Responsible agricultural mechanization innovation for the sustainable development of Nepal's hillside farming system. *Sustainability*, 12(1): 374.

Díaz S, Fargione J, Chapin III FS, Tilman D 2006. Biodiversity loss threatens human well-being. *PLoS Biol,* 4(8): e277.

Erisman JW, van Eekeren N, de Wit J, Koopmans C, Cuijpers W, Oerlemans N, Koks BJ 2016. Agriculture and biodiversity: A better balance benefits both. *AIMS Agriculture and Food*, 1(2): 157-174.

FAO 2007. Papers Submitted: International Conference on Organic Agriculture and Food Security. Rome. From <ftp://ftp.fao.org/paia/organicag/ofs/OFS-2007-INF-rev.pdf.> (Retrieved on 24 July 2020).

Fiebrig I, Zikeli S, Bach S, Gruber S 2020. Perspectives on permaculture for commercial farming: aspirations and realities. *Organic Agriculture*, 1-16.

Ghersa CM 2012. Agroecological basis for managing biotic constraints. *Encyclopedia of Sustainability Science and Technology*, 50-61.

Giller KE, Witter E, Corbeels M, Tittonell P 2009. Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research*, 114(1): 23-34.

Gliessman SR 1998. *Agroecology: Ecological Process in Sustainable Agriculture*. Michigan: Ann Arbor Press.

Gliessman SR 2014. *Agroecology: The Ecology of Sustainable Food Systems*. Boca Raton, London, New York: CRC Press.

Gliessman S, Friedmann H, Howard PH 2019. Agroecology and food sovereignty. *IDS Bulletin*, 50(2): 684-685.

Gomiero T, Pimentel D, Paoletti MG 2011. Environmental impact of different agricultural management practices: conventional vs. organic agriculture. *Critical Reviews in Plant Sciences*, 30(1-2): 95-124.

Govaerts B, Verhulst N, Castellanos-Navarrete A, Sayre KD, Dixon J, Dendooven L 2009. Conservation agriculture and soil carbon sequestration: Between myth and farmer reality. *Critical Reviews in Plant Science*, 28(3): 97-122.

Halberg N, Sulser TB, Høgh-Jensen H, Rosegrant MW, Knudsen MT 2006. The impact of organic farming on food security in a regional and global perspective. *Global Development of Organic Agriculture: Challenges and Prospects*, 277-322.

Hecht SB 1995. The evolution of agroecological thought. In: MA Altieri (Eds.): *Agroecology: The Science of Sustainable Agriculture*. 2nd Edition. Boulder, CO: Westview, pp. 1-19.

Holt-Giménez E 2002. Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: A case study in participatory, sustainable land management impact monitoring. *Agriculture, Ecosystems and Environment*, 93(1-3): 87-105.

Ibeawuchi II, Obiefuna JC, Iwuanyanwu UP 2015. Low external input agricultural farming system for the increase in productivity of resource poor farmers. *Soil and Water*, 5(2): 1-9.

IFOAM 2007. Final Draft on the Definition of Organic Agriculture. From <http://www.ifoam.org/growing_ organic/definitions/sdhw/pdf/Final_Draft_ Definition_of_ Organic_Agriculture.pdf> (Retrieved on 24 July 2020).

Isgren E 2016. No quick fixes: Four interacting constraints to advancing agroecology in Uganda. *International Journal of Agricultural Sustainability*, 14(4): 428-447.

Kelly C 2009. *Lower External Input Farming Methods as a More Sustainable-solution for Small-scale Farmers*. Doctoral Dissertation. Stellenbosch: University of Stellenbosch.

Killebrew K, Cullen A, Anderson CL 2009. *Ecological farming. Evans Policy Analysis and Research (EPAR)*. Washington.

Kirchmann H Bergstrom L (Eds.) 2008. *Organic Crop Production—Ambitions and Limitations*. New York: Springer.

Kramer SB, Reganold JP, Glover JD, Bohannan BJ, Mooney HA 2006. Reduced nitrate leaching and enhanced denitrifier activity and efficiency in organically fertilized soils. *Proceedings of the National Academy of Sciences*, 103(12): 4522-4527.

Kremen C, Iles A, Bacon C 2012. Diversified farming systems: An agroecological, systems-based alternative to modern industrial agriculture. *Ecology and Society*, 17(4): 1-19.

Kumar S, Meena RS, Jakhar SR, Jangir CK, Gupta A, Meena BL 2019. Adaptation strategies for enhancing agricultural and environmental sustainability under current climate. In: RS Meena (Ed.): *Sustainable Agriculture*. Jodhpur: Scientific Publisher, pp. 226-274.

Lampkin N, Pearce B, Leake A, Creissen H, Gerrard CL, Gerling R, Lloyd S, Padel S, Smith J, Smith L, Vieweger A 2015. The Role of Agroecology in Sustainable Intensification. From <https://www.nature.scot/role-agroecology-sustainable-intensification-lupg-report> (Retrieved on 28 June 2020).

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

Magrini MB, Martin G, Magne MA, Duru M, Couix N, Hazard L, Plumecocq G 2019. Agroecological transition from farms to Territorialised agri-food systems: Issues and Drivers. In: Jacques-Eric Bergez, Elise Audouin, Olivier Therond (Eds.): *Agroecological Transitions: From Theory to Practice in Local Participatory Design*. Cham: Springer, pp. 69-98.

MacRae RJ, Hill SB, Mehuys GR, Henning J 1990. Farm-scale agronomic and economic conversion from conventional to sustainable agriculture. *Advances in Agronomy*, 43: 155-198.

Mercer DE 2004. Adoption of agroforestry innovations in the tropics: A review. *Agroforestry Systems*, 61(1-3): 311-328.

Nandwa SM, Bekunda MA 1998. Research on nutrient flows and balances in East and Southern Africa: State-of-the-art. *Agriculture, Ecosystems and Environment*, 71(1-3): 5-18.

National Research Council 2010. *Toward Sustainable Agricultural Systems in the 21st Century*. Washington, D.C., U.S.A.: National Academies Press.

Nicholls CI, Altieri MA, Vazquez L 2016. Agroecology: Principles for the conversion and redesign of farming systems. *Journal of Ecosystem and Ecography*, S5: 1.

Oberè BP, Arroyo Schnell A 2020. *Approaches to Sustainable Agriculture. Exploring the Pathways towards the Future of Farming*. Brussels, Belgium: IUCN EURO.

Oliver MJ 2014. Why we need GMO crops in agriculture. *Missouri Medicine*, 111(6): 492.

Otsuka K, Muraoka R 2017. A green revolution for sub-Saharan Africa: Past failures and future prospects. *Journal of African Economies*, 26(Suppl 1): i73-i98.

Parrott N, Olesen JE, Høgh-Jensen H 2006. Certified and non-certified organic farming in the developing world. *Global Development of Organic Agriculture: Challenges and Prospects*, 153-176.

Pearson CJ 2007. Regenerative, semiclosed systems: A priority for twenty-first-century agriculture. *Bioscience*, 57(5): 409-418.
Pender J, Mertz O 2006. Soil fertility depletion in Sub-Saharan Africa: What is the role of organic agriculture? *Global Development of Organic Agriculture: Challenges and Prospects*, 215-240.
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 JN, Morison JI, Hine RE 2003. Reducing food poverty by increasing agricultural sustainability in developing countries. *Agriculture, Ecosystems and Environment*, 95(1): 217-234.
Pretty JN, Noble AD, Bossio D, Dixon J, Hine RE, Penning de Vries FW, Morison JI 2006. Resource-conserving agriculture increases yields in developing countries. *Environ Sci Technol*, 40(4): 1114-1119.
Pretty J 2008. Agricultural sustainability: Concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1491): 447-465.
Pretty J, Sutherland WJ, Ashby J, Auburn J, Baulcombe D, Bell M, Bentley J, Bickersteth S, Brown K, Burke J, Campbell H 2010. The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8(4): 219-236.
Pretty J, Bharucha ZP 2014. Sustainable intensification in agricultural systems. *Annals of Botany*, 114(8): 1571-1596.
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, Cáceres D 2001. Organic farming and the sustainability of agricultural systems. *Agricultural Systems*, 68(1): 21-40.
Rosset PM, Altieri MA 1997. Agroecology versus input substitution: A fundamental contradiction of sustainable agriculture. *Society and Natural Resources*, 10(3): 283-295.
Sagastuy M, Krause T 2019. Agroforestry as a biodiversity conservation tool in the Atlantic Forest? Motivations and limitations for small-scale farmers to implement agroforestry systems in north-eastern Brazil. *Sustainability*, 11(24): 6932.
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(2-3): 109-136.
Schoonhoven Y, Runhaar H 2018. Conditions for the adoption of agro-ecological farming practices: a holistic framework illustrated with the case of almond farming in Andalusia. *International Journal of Agricultural Sustainability*, 16(6): 442-454.
Sherwood S, Uphoff N 2000. Soil health: Research, practice and policy for a more regenerative agriculture. *Applied Soil Ecology*, 15(1): 85-97.
Shiferaw BA, Okello J, Reddy RV 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.
Silici L 2014. Agroecology: What It Is and What It Has To Offer. *Issue Paper* 14629IIED. London: International Institute for Environment and Development.
Sinclair F, Wezel A, Mbow C, Chomba S, Robiglio V, Harrison R 2019. *The Contribution of Agroecological Approaches to Realizing Climate-resilient Agriculture*. Rotterdam, The Netherlands: GCA.
Therond O, Duru M, Roger-Estrade J, Richard G 2017. A new analytical framework of farming system and agriculture model diversities. A review. *Agronomy for Sustainable Development*, 37(3): 21.
Thorn JP, Friedman R, Benz D 2016. What evidence exists for the effectiveness of on-farm conservation land management strategies for preserving ecosystem services in developing countries? A systematic map. *Environmental Evidence*, 5(1): 13.
Tomich TP, Brodt S, Ferris H, Galt R, Horwath WR, Kebreab E, Leveau JH, Liptzin D, Lubell M, Merel P, Michelmore R 2011. Agroecology: A review from a global-change perspective. *Annual Review of Environment and Resources*, 36: 193-222.
Tripp R 2006. Is Low External Input Technology Contributing To Sustainable Agricultural Development. Natural Resource Perspectives, 102. From <http://hdl.handle.net/10535/4075> (Retrieved on 12 May 2021).
United Nations Environment Programme-United Nations Conference on Trade and Development Capacity Building Task Force on Trade, Environment and Development (UNEP-UNCTAD) 2008. Organic agriculture and food security in Africa. From <https://unctad.org/en/Docs/ditcted200715_en.pdf> (Retrieved on 24 July 2020).
Vaarst M, Escudero AG, Chappell MJ, Brinkley C, Nijbroek R, Arraes NA, Andreasen L, Gattinger A, De Almeida GF, Bossio D, Halberg N 2018. Exploring the concept of agroecological food systems in a city-region context. *Agroecology and Sustainable Food Systems*, 42(6): 686-711.
Vanlauwe B, Kihara J, Chivenge P, Pypers P, Coe R, Six J 2011. Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. *Plant and Soil*, 339(1-2): 35-50.
Wezel A, Casagrande M, Celette F, Vian JF, Ferrer A, Peigné J 2014. Agroecological practices for sustainable agriculture. A review. *Agronomy for Sustainable Development*, 34(1): 1-20.
Wezel A, Goette J, Lagneaux E, Passuello G, Reisman E, Rodier C, Turpin G 2018. Agroecology in Europe: Research, education, collective action networks, and alternative food systems. *Sustainability*, 10(4): 1214.
Zhu X, Clements R, Haggar J, Quezada A, Torres J 2011. *Technologies for Climate Change Adaptation-Agriculture Sector*. Denmark: UNEP-DTU Partnership; New Delhi, India: Magnum Custom Publishing.

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