Agroecology: A Pathway to a new Model for Agriculture in Hawaii

Hector Valenzuela, Ph.D.
Department of Plant and Environmental Protection Sciences,
University of Hawaii at Manoa

Albie Miles, Ph.D
Associate Professor, Sustainable Community Food Systems
University of Hawai'i - West O'ahu

Index

1.0. Introduction, pg. 2
2.0. The building-blocks of an agricultural system in transition, pg. 2
3.0. What is Agroecology?, pg. 5
4.0. Prospects for the adoption of Agroecology in Hawaii, pg. 10
- 4.1. Introduction
- 4.2. Environmental Challenges posed by the Industrial Model of Agriculture in Hawaii
- 4.3. A Road-map for Agroecology adoption in Hawaii
- 4.4. Integrated Food Policy Recommendations

5.0. Success stories from the adoption of agroecology, pg. 18
6.0. References, pg. 21

Tables:

Table 1. Key terms and definitions related to the scientific and social field of Agroecology, pg. 7

Table 2. Some Agroecology-based implementation strategies based on the five principles of diversity, efficiency, natural regulation, synergies, and recycling, Pg. 9

Table 3. Some of the reported benefits from the adoption of agroecology or organic farming practices, pg. 19

Table 4. Success stories from the adoption of agroecological practices, pg. 20

1.0. Introduction

This paper makes a case for the conversion of agriculture in Hawaii towards Agroecology, a scientific system of agriculture that is based on ecological concepts and principles as well as on social values that promote food sovereignty, affirmation of indigenous and cultural identity, and rural economic well-being. The purpose of agroecology is to reduce the dependence on external inputs, to improve the efficiency of biological processes on the farm that will improve internal mechanisms of pest control and nutrient cycling, and promoting production programs that are environmentally, socially and culturally responsible (Kerr, 2020).

To begin, this paper provides an overview of fundamental social, institutional and production factors, in other words, the building-blocks, that have an impact on the future of agriculture in Hawaii. Following this, a definition of Agroecology is provided along with the central concepts that describe its science and philosophy. The paper then provides a perspective on how farming systems in Hawaii can transition to adopt agroecological methods of production. Central aspects of the Agroecological Model that can help to regenerate the health of agricultural systems in Hawaii include:

i) Restore and maintain soil fertility in production areas that have experienced historical high levels of soil erosion, pesticide contamination, and degradation of soil quality and fertility.

ii) Develop resilient production systems that can better withstand the imminent impacts of climate change in the form of increased periodic droughts and flooding events, and warmer temperatures.

iii) Develop resilient communities and local food systems, to improve food self-sufficiency in the state.

iv) Develop community-based farming systems that support the indigenous and cultural identity and values of the community, improving levels of food security and sovereignty, and allowing local communities to have a greater say about the future of the food system in their communities, and preservation of their environment and traditional life-styles.

The paper concludes with a proposed road map of specific steps that may be taken at the state and institutional level to begin a path towards the adoption of an agroecological model in Hawaii.

2.0. The building-blocks of an agricultural system in transition

It has been over 30 years since the closure of the plantations began to change the picture and structural dynamics of agriculture in Hawaii. In the meantime considerable debate continues about the future of land use and agriculture in the state (Valenzuela, 1992 & 2009). Different visions that have been put forth about the future of agriculture in Hawaii include a continuation of the plantation ‘model’ of agriculture guided by large-scale out-of-state corporate operations;

conventional or industrial production systems dependent on external inputs such as fuel, fertilizers, and pesticides; capital intensive greenhouse or protected agriculture systems (Comeford, 2020); as well as a vision towards support of small-scale community-based sustainable, organic and agroforestry production systems that rely on locally-available natural resources.

Several key economic, environmental, social, cultural, technical, and institutional factors play a central role that will help determine the future of agriculture in Hawaii:

- **Economics**. From an economic perspective, the challenge includes the difficulty of producing crops in Hawaii, given the high costs of production (La Croix and Mak, 2021, link, https://uhero.hawaii.edu/reviving-agriculture-to-diversify-hawaiis-economy/). Because of the high costs of production, including access to land and labor, water, and external inputs, farmers have a difficulty to grow crops profitably and to compete with the value of imported produce. The high cost of production, including access to land and labor, also makes it prohibitive to start new farming operations in Hawaii, for most prospective new farmers.
- **Environment.** From an environmental perspective farmers are increasingly faced with more stringent government regulations that restrict the indiscriminate use of pesticides and chemical fertilizers. The ongoing and specter of climate change, also represents considerable challenges for farming in Hawaii as illustrated by the periodic and increasing intensity of droughts and floods experienced over the past 30 years in the state (Altonn, 2003; Kubota, 2010; Madson et al., 2023).
- **Food Self-sufficiency and access to Nutritious food**. From a social perspective, and given Hawaii's geographic isolation, and susceptibility to environmental impacts, interest has risen for Hawaii to become more self-sufficient in food production (DBEEDT, 2012, Lincoln, 2016), and for Hawaii farmers to adopt more environmentally conscious methods of crop production. In Hawaii several sectors of the community experience significant levels of chronic food insecurity, including 1 in 6 adults and 1 in 4 children (Stupplebeen, 2019; Kohala Center, 2012; Shirota, 2021), as well as diet-related health issues, such as diabetes and obesity. There is thus a need to increase both the access to nutritious food through the increased consumption of locally-grown fruits and vegetables.
- **Indigenous and cultural Identity**. As a challenge to the dominant neocolonial Western and corporate-based model of Industrial agriculture, communities within the state are increasingly prioritizing the importance of recognizing their Indigenous, ethnic and cultural values with the goal of developing local food and production systems that reflect those values (Gon and Winter, 2019; Kurashima et al., 2019). Because of the millennial knowledgebase of indigenous farming in Hawaii and of their sister immigrant cultures, representing proven models of self-sufficiency and sustainability, rural communities within the state are also developing a vision about the future of agriculture in their communities (Hamakua Ag Plan, 2006; North Kohala Ag Plan, 2008), that reflect the values that are ingrained as part of this rich cultural heritage.

- **Technical knowledge and support and access to Economic Data**. From a technical perspective, due to its geographical isolation, farmers in Hawaii also find it challenging to find the technical expertise or guidelines on how to grow profitably the wide range of crops grown in the state (for example, over 250 vegetable and herb species alone, are grown commercially or by home-gardeners in the state). Farmers or gardeners that aim to grow these crops organically, without the use of external inputs, find it even more difficult to find the appropriate technical research-based information, given that the bulk of the agricultural research conducted in the state over the past 70 years has been focused on the production of crops that rely on the use of external inputs (synthetic pesticides and fertilizers). Without access to the appropriate technical expertise for the production of specific crops, farmers in Hawaii will experience a steep learning curve, and a relative low efficiency of production (such as with the use of irrigation, field equipment, or labor), which further decreases their unit-price competitiveness with respect to other regions with higher production efficiency and lower production costs (such as in the continental U.S., Asia, or Latin America) (LaCroix and Mak, 2021; Adeoye, 2020; Haji and Andersson, 2015). In addition to technical information, established and prospective farmers also need access to timely economic data and market statistics, to help them decide what crops to grow and to design a marketing strategy (Adrian et al., 1989; Blandon and Falk, 2012)- however local cost of production studies for individual crops, and periodic marketing statistics, have been starkly unavailable in Hawaii, for many years.
- **Institutional support**. Institutional barriers, resistant to structural change, represent another challenge to alter or modify patterns of land use, land distribution, and methods of farming in Hawaii (Sayer and Cassman, 2013). Because patterns of land use and industrial methods of farming are historically deeply ingrained within local institutions including the dominant business and banking sector, conventional farms, academic institutions, and media and government agencies; it has been difficult to discuss, articulate, validate and to legitimize alternative visions for the future of agriculture in the state. Several eminent Science Panel assessment reports, have emphasized that land grant universities in the U.S.A. should challenge the narrative and structure of mainstream Industrial Agriculture, to develop more inclusive educational and research programs to better support small family farms and to promote more sustainable methods of farming (DeLonge et al., 2016; NRC, 2002; Volkner et al, 1998; Kohala Center, 2011). Similarly, state sister institutions should modify long-standing policies that have historically supported plantation and corporate-based agriculture, large landowners and business interests in the state.

3.0. What is Agroecology?

The science and practice of agroecology has been put forward to challenge the mainstream model of Industrial or Conventional agriculture. The environmental and health problems that result from Industrial or so called “Green Revolution” methods of farming include the loss of biodiversity; pest outbreaks; human health; dependence on fossil-fuels; contribution to greenhouse gas emissions; exposure to chemicals used on the farm; contamination of the groundwater and aquatic habitats; consolidation of the farming industry; and agro-export policies that result in land dispossession by peasant and indigenous farmers, food insecurity, and in social inequity (Carpenter, 1994; Ehlrich and Harte, 2015; Valenzuela, 2016).

About 35 years ago it was recognized by a National Scientific Panel that in the U.S. the adoption of alternative production practices “would result in even greater benefits to farmers and environmental gains for the nation,” compared to the Industrial methods of farming (Carpenter, 1994; NRC, 1989). Eminent professors from Stanford and UC Berkeley stated in the prestigious journal of the Proceedings of the National Academy of Sciences that to feed a growing global population the food system would require a ‘global revolution.’ Their recommendations to achieve this ‘revolution’ included to reduce the adverse externality costs of Industrial agriculture, and to “Greatly expand research that can lead to more ecologically sound cropping systems, with more emphasis on long-term sustainability as opposed to immediate yield” (Ehlrich and Harte, 2015).

Broadly, agroecology may be defined as the science that applies ecological concepts and principles for the design of agricultural systems, while including a strong social component to ensure that the production system is both environmentally sound and socially responsible (Wezel et al., 2009; Rosset and Altieri, 2017; HLPE, 2019) (Table 1). As such agroecology has been conceptualized as a science, to improve production systems through the adoption of ecologically-based sound agricultural practices, but also as a social and political movement that promotes social and gender equity, community food sovereignty, and the preservation of indigenous rights and cultural identity (ECVC, 2021; Rosset and Altieri, 2017). While agroecology was originally focused in developing countries, it is increasingly being adopted to support small-scale family farms in developed countries such as in Europe and the U.S. (Guareschi et al., 2020, Donham and Wezel, 2022). Agroecology is also increasingly being recognized as a system that improves farm resilience for better adaptation to the impending impacts of climate change (Mottram et al., 2017; Donham and Wezel, 2022; Snapp et al., 2021). Refer to Table 1 for a list of definitions related to Agroecology.

From an ecological perspective, agroecology aims to improve the efficiency of biological processes in the farm, such as biological control for pest management, as well as to improve internal nutrient and water cycles. The goal is to improve the efficiency of internal biological and ecological processes, while minimizing the use of external inputs. Some of the strategies promoted through the adoption of agroecological practices are described in Table 2. The fundamental areas of a Sustainable system that are promoted by Agroecology include, a)

Environmental health, b) Economic well-being; c) Social equity); and d) Food Sovereignty: the ability of local communities to decide what is grown, how, and for whom (De Molina and Lopez-Garcia, 2021)

It should be emphasized that Agroecology does not represent simply a new set of production practices. Instead Agroecology should be recognized as a paradigm shift that proposes a new Model of Agriculture that challenges current Industrial or conventional methods of farming (Valenzuela, 2016). As such Agroecology does not consist of the simple substitution of one production practice for another, or of one input for another, but instead it represents a restructuring of the entire agriculture and food system, based on the adoption of ecological principles, social well-being and equity (Donham et al., 2022). Furthermore, Agroecology does not represent a one-size-fits all, in terms of its definition, adoption, and implementation. Both its definition, in general terms, and its implementation will be molded and adapted according to the particular environmental, cultural, and socioeconomic conditions of individual locations, by following a fully participatory approach during all stages of its planning, design, and implementation (HLPE, 2019). Overall, agroecology is increasingly being recognized as an alternative to the model of Industrial Agriculture with the goal of improving resilience against the impacts of climate change, resulting in an agricultural transition towards the establishment of sustainable food systems and increased food security and nutrition (Valenzuela, 2016; HLPE, 2019).

The strong social component and political aspect of agroecology, espoused by the international movement of La Via Campesina and other grass-roots movements around the world, is articulated by (Rosset and Altieri, 2017):

> *"We need to decolonize agroecology and resist current global, rent-seeking, dispossessing, capitalist mechanisms; and the defense of agroecology needs to recover a sense of the commons. This implies continued rejection of agribusiness models, large landholdings and economic globalization, while defending territories from attempts by capital to expand into new geographic spaces and continuing mobilizations aimed at gaining control of production, distribution and consumption."*

As part of this agricultural social justice movement, Holtz-Giménez et al (2021) add,

> *"Agroecology is one tool in the fight for what grassroots organizations are calling a 'just transition' – a transformation from economic and ecological systems which are fundamentally extractive, to resilient food systems that begin by addressing systemic inequities"*

Table 1. Key terms and definitions related to the scientific and social field of Agroecology

Term	Definition	Citations
Ecology	A branch of biology that studies the interactions of organisms with each other and their given environments. There are several different types of ecology based on the specific levels being studied, such as molecular ecology, organismal/behavioral ecology, population ecology, community ecology, and ecosystem ecology	(Odum, 1953; Christensen et al., 1996)
Agroecology	A scientific discipline that uses ecological theory and research methods to study, design, and manage agricultural ecosystems that are productive and resource conserving. Agroecology has been defined as a scientific discipline involving the study of biophysical interactions in agro-ecosystems, including human and environmental elements; a set of principles and practices to enhance the resilience and ecological sustainability of farming systems; and an agrarian-based social movement seeking a new way of considering agriculture and its relationships with society (Agroecology Info Pool 2019). Agroecology not only deals with the physical aspects of agriculture, but also includes studying the social, political, historical, cultural, and economic factors that contribute to influencing agroecosystems	(Altieri, 1987; Peano and Sottile, 2017)
Sustainability	The ability to support or maintain a process continuously over time without degrading the integrity of surrounding systems or organisms contained within	(DeLonge et al., 2016; NRC, 2010)
Ecological sustainability	The ability to maintain systems involving complex interactions between individual organisms, populations, communities, and ecosystems. For example, the use of renewable energy sources which harness the abundance of natural resources that cannot be depleted, such as wind, solar, hydroelectric, and biomass	(Christensen et al., 1996; DeLonge et al., 2016)
Agroecological sustainability	The ability to support and maintain agricultural ecosystems to ensure food security and overall food system resilience. Sustainable agroecosystems rely less on external inputs, manage pests and pathogens internally, and recover themselves from cultivation and harvesting processes. For example, the use of cover crops, crop rotations, organic matter cycling, efficient water and nutrient management, invasive species management, biological control strategies, and renewable energy usage	(Altieri, 1987; DeLonge et al., 2016; Peano and Sottile, 2017)
Ecosystem services	The processes taking place in nature that human beings benefit from in order to facilitate healthy, productive lives. These services provide us with clean water, food, fiber, and fuel by cycling nutrients, maintaining biodiversity, regulating pests and pathogens, pollinating crops, filtering water, generating new soils, mitigating erosion, and dispersing seeds	(Christensen et al., 1996; NRC, 2010)
Food Sovereignty	““Food Sovereignty is the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems”	Akanmu et al., 2023, citing Huambachano, (2019); Via Campesina, 2015
Aloha ʻĀina	Literally, ‘love for the land’ it is described by native Hawaiians as “a recognition, commitment, and practice sustaining the ea – or life breath – between people and our natural environments that resulted in nearly 100 generations of sustainable care for Hawaiʻi. We recognize that it is because of the aloha ʻāina practiced by Native Hawaiians over many centuries that we can enjoy the Hawaiʻi we have today.” Citing Prof. Noelani Goodyear-Kaopua, Sproat and Palau-McDonald (2022) add that	Gupta, 2014; Sproat and Palau-McDonald (2022)

	“aloha 'aina "mean[s] not only a love for the land, but a real deep and personal sense of connection to place, an unswerving commitment to the health of our natural world" and the human communities reliant upon it.”	

Table 2. Some Agroecology-based implementation strategies based on the five principles of diversity, efficiency, natural regulation, synergies, and recycling (Akanmu et al., 2023) (note that the focus is on the application of ecological and biological principles and concepts, NOT on input-substitution).

Agroecology Strategy	**Effects on the Farm**	**Citations**
Vegetational diversification (inc. agrobiodiversity, habitat manipulation, intercropping, rotations)	Pest management, biocontrol, nutrient cycling, soil quality, food security, risk management	Donham and Wezel, 2022; Snapp et al., 2021; Jarvis et al., 2011; Valenzuela, 2000; Witcombe et al., 2023;
Reliance on local Resources	Energy Efficiency, lower costs of production, nutrient cycling	Donham and Wezel, 2022; Valenzuela, 2023
Integrated crop-livestock and crop-aquaculture systems	Improved resource utilization, risk management, nutrient cycling	Bonaudo et al., 2014; Costa-Pierce, 2022; Donham and Wezel, 2022; Francis and Porter, 2011; Farrant et al., 2021; Valenzuela, 2023;
Agroforestry adoption	Improved resource use and resilience, biodiversity	Leakey, 2014; Donham and Wezel, 2022; Valenzuela, 2023
Landscape mosaics	Biodiversity, pest management, resilience	Snapp et al., 2021; Sayer and Cassman, 2013
Biocontrol and alternative pest management	Pest and weed management	Snapp et al., 2021; Valenzuela 2000; Valenzuela, 2015
Nutrient cycling, organic amendments	Crop growth, pest control, soil quality	Drinkwater and Snapp, 2007; Valenzuela, 2000; Valenzuela, 2023
Soil quality	Biocontrol, Nutrient and water cycles, crop productivity	Pimentel, 2011; Tiemann et al., 2015; Valenzuela 2000; Valenzuela, 2023
Cover crops, Legumes, Nitrogen fixation	Improved nutrient cycles, pest and weed management, soil quality	Snapp et al., 2021; Drinkwater and Snapp, 2007; Valenzuela, 2000
Ecosystem services	Pest biocontrol, nutrient cycling, soil quality, plant growth	Kremen and Miles, 2012; Rehman et al., 2022
Participatory, multi-stakeholder, and co-knowledge generation	Increased innovation and adoption of new practices	Donham and Wezel, 2022; Snapp et al., 2021; EVCV, 2021; Vermeulen et al., 2013
Social justice programs	Food sovereignty, cultural identity	Bezner Kerr et al., 2022; Rosset and Altieri, 2017

4.0. Prospects for the adoption of Agroecology in Hawaii

4.1. Introduction

Warnings have been raised over the past decades about the imminent environmental impacts of Climate Change and of Industrial Agriculture (Borenstein, 2023, Ehrlich and Harte, 2015; Hayes and Hansen, 2017; Valenzuela, 2016). The adverse impact on biodiversity and ecosystem services (Tables 1 and 2), degradation of agricultural lands and fisheries and increased frequency of extreme climatic events, will impact the productivity of crops and fisheries in the foreseeable future. The concept of "Earth system justice" has been put forward to address the unequal environmental impacts of environmental degradation on different social groups, based on income, gender, geographic location, or ethnic background (Gupta et al., 2023). As indicated earlier, the concept of social justice, equity and sovereignty is also ingrained within the philosophy and movement of Agroecology (Rosset and Altieri, 2017). For example, a recent review of the literature indicated that "There is considerable evidence that agroecology can improve social well-being, in part through increased food security and improved dietary diversity, which often contributes to culturally meaningful foodways" (Bezner Kerr et al, 2022).

Because, as a microcosm of the world, Hawaii faces some of the same environmental impacts from climate change and industrial methods of farming, it is important that the state re-evaluates its current model of agriculture, economy, and its overall food system (farm to table) (Kerr, 2020; Beamer et al., 2023). Similar calls have been made for many years in the U.S., by eminent national scientific panels, calling for a restructuring of the food system in the U.S., including the programmatic activities of the land grant university system; as well as calling for the support for small farms and for the adoption of alternative methods of farming (Volkmer, 1998; Jolly, 1999; NRC, 1989; NRC, 2002). While some critics claim that adoption of Alternative agriculture methods results in lower yields, a review of the literature indicated that "In both organic and conservation agriculture, different combinations of crops, climate and diversification practices outperformed industrial agriculture, and thus we find little evidence that high input systems always outperform alternative forms of agriculture," and further determined that crop yields are not actually correlated to whether people are being fed (Ponisio and Ehrlich, 2016).

Agroecology represents a new paradigm that encompasses the entire food system with the goal to develop more sustainable and socially just systems of production (Valenzuela, 2016, Bezner Kerr et al., 2022; Rosset and Altieri, 2017) (Table 1). Again, agroecology does not represent simply the adoption of new production practices, or the substitution of one input for another, but rather a re-engineering of the current food system, to develop more sustainable and socially inclusive methods of production. The nature and adoption of the Agroecological Model in Hawaii would thus be molded based on the local social and environmental setting, and may include innovative approaches that incorporate both the Hawaiian concept of Aloha ʻĀina (Sproat and Palau-McDonald, 2022), with alternative economic models, such as those proposed by a circular economy (Table 1; Beamer et al., 2021; Beamer et al., 2023; Winter et al., 2023).

4.2. Environmental Challenges posed by the Industrial Model of Agriculture in Hawaii

A multitude of complex ecological issues affect the Hawaiian Islands. These problems include habitat destruction and loss, a significant and growing number of extinct and endangered plants and animals, increasing demand for food production, the depletion and wasting of natural resources, an increased human presence and urban development, and high rates of pollution (Winter et al. 2020). Since the early 1900s, Hawai‘i has experienced alarming rates of land, ocean and waterway pollution from the U.S. military (e.g. sea disposal of more than 16,000 M47A2 100-lb mustard-filled bombs, dumped around Pearl Harbor in 1944) (Edwards et al. 2016). Additionally, aquifer recharge is taking longer and surface water runoff is increasing, while soil erosion and landslides are more frequent and coral reefs are deteriorating at a high rate. Climate change (CC) models predict windward areas of the Hawaiian Islands will likely remain consistent with current rainfall levels, however, leeward areas are expected to become increasingly drier (Ghazal et al., 2019). At one time, there were an estimated 330-350 loko i‘a (fishponds) in Hawai‘i, producing anywhere from 300-500 pounds of fish per acre. Currently, there are about 56 sites with the potential for revitalization as functional, productive loko i‘a (Keala, 2007). Forty one percent of Hawai‘i’s agricultural lands are currently not being utilized for food production while the island chain remains dependent upon food importation at a rate of eighty seven percent (Kurashima et al. 2019). Since 1778, roughly 91 species of mammals and birds have been introduced in Hawai‘i for hunting (Duffy & Lepczyk 2021). Hawai‘i’s fruit and vegetable production depends on pollinators, however, there are not sufficient studies to appropriately assess ecological roles nor to make optimal management recommendations. In addition, many populations of pollinators have experienced declines over the past 30 years due to pests, pathogens, parasites, pesticide use, and habitat loss (Valenzuela 2018). Much of the archipelago’s uncultivated agricultural land is inundated with invasive plant and animal species, threatening roughly ninety percent of endemic plant life (Kurashima et al. 2019).

4.3. A Roadmap for Agroecology adoption in Hawaii

Below is a description of some of the strategies that may be implemented to begin a transition towards Agroecology in Hawaii.

4.3.1. Protect Natural Resources

Policies that protect natural resources such as water, soil, and biodiversity can improve soil health, reduce water pollution, and increase carbon sequestration, thereby supporting sustainable agriculture. This includes policies that promote conservation practices, reduce the use of chemical fertilizers and pesticides, and regulate water and land use.

4.3.2. Support small-scale agriculture

Public policies that support small and mid-sized farmers can help create a more diversified agricultural sector; support local economies and revitalization of rural economies; improve labor conditions; and provide resilient communities. This includes funding programs and technical assistance that help farmers transition to agroecological, sustainable and organic farming practices, such as offering education and outreach programs on agroecology and agroforestry.

A national scientific panel report published over 40 years ago challenged the structure of agriculture in the U.S., which was leading to consolidation of the industry into fewer and fewer players. A follow-up panel report published about 20 years later (Volkmer, 1998) indicated that the warnings had not been heeded, leading towards an even greater consolidation of the industry into larger farms and fewer players in the food system. The follow-up report called for institutional changes at the government and land grant University level, to support the growth of more small farms which can contribute greatly to community food security, improve rural economies, raise families, support cultural and traditional rural lifestyles, and to the "strengthening of society" (Volkmer, 1998). The value of small farms to improve food security, to provide climate change resilience, to protect rural lifestyles, and for rural economic development, is increasingly being recognized at the global and regional level (IFAD, 2013; Chancellor, 2019; Rocha et al., 2012; Cardillo and Cimio, 2022). Recent analyses also indicate that small farms result in greater yields, productivity and biodiversity, than larger farms (Ricciardi et al., 2021).

Small farms in Hawaii represent over 90% of all farms in the state, their sales represent over 50% of the agricultural products sold in the state, and provide 72% of the direct sales to consumers in the state (NASS, 2021). However, considerable support is needed from government institutions and from the University system to help farms a) increase their competitiveness against imports; b) develop alternative marketing channels; and c) transition to Agroecology. A transition to agroecology would decrease farms' dependence on external inputs, would increase their resilience to withstand the impacts of climate change; and would allow small farms to better meet the consumer and food service demand for healthy, pesticide-free, nutritious, and locally grown food.

4.3.3. Support local food systems

Supporting local food systems can create jobs and reduce environmental impacts associated with transportation, processing, and packaging. Public policies promoting infrastructure such as farmers' markets, food hubs, food co-ops, and financing resources, can help support small farmers and sustainable agriculture (Berning et al., 2022; OPSD, 2018). These efforts can learn from the experience of several innovative online and brick and mortar projects adopted in the islands over the past decade, supporting local food systems. One approach to promote sustainable and environmentally responsible local food systems involves the creation of "Bio-districts." An alternative food network organized as part of the Parma bio-district in northern Italy, popular for its tomato and wine industry, follows the principles of a circular economy and zero waste and promotes "nutrition education, respect for the environment and social responsibility." In bio-districts, organic or agroecological production practices are integrated with local artisanal activities, tourism, recreation, and aim to protect the environment, biodiversity, and the socio-cultural aspects of the region (Guareschi et al., 2020). The bio-district approach may also be effective to disseminate or upscale the adoption of agroecology in the region (Lopez-Molina and González de Molina, 2021).

4.3.4. Indigenous knowledge and community input is Integral to Agroecology

Along with the current scientific understanding about modern agricultural practices, Indigenous knowledge should be a foundation for the design and development of resilient production systems in Hawaii (Gon et al, 2018). Given the millennial knowledge of the Hawaiian culture that subsisted on the islands for hundreds of years as part of an intimate relationship with nature (Winter et al., 2020), it serves as a model of self-sufficiency, management of natural resources, ancestral crop preservation, and of our understanding of crop niche adaptation to the diverse variety of ecological habitats in the state (Kagawa-Viviani et al., 2018; Kurashima et al., 2019; Lincoln, et al., 2023). Our more recent understanding about the resource management strategies used by Hawaiians to grow crops such as breadfruit and sweetpotato, can serve as a valuable model for the design of innovative agroecological programs to grow crops under particularly challenging growing conditions (Lincoln and Ladefoged, 2014; Lincoln, 2020; Sirabis et al., 2022). Indigenous knowledge is especially valuable when designing systems where local environmental adaptability is crucial, such as with agroforestry (Hastings et al., 2022) or aquaculture (Costa-Pierce, 2022). The millennial knowledge brought to Hawaii from immigrant cultures, such as from Asia, as well as the one that has been incorporated as part of the organic farming movement, will complement the Hawaiian indigenous knowledge, to optimize natural resource conservation and resilient agricultural practices in the state.

4.3.5. An Ahupua'a or watershed based approach to protect biodiversity, land, nutrient and water resources

A central aspect of land management, a legacy of Hawaiians' millennial knowledge, is the watershed or ahupua'a land, nutrient, and water management approach (Winter et al., 2023). The ahupua'a method of land management provides a holistic landscape or area-wide approach to optimize nutrient and water cycles and use of green vegetation "corridors" which provide several ecological services such as biodiversity, and as as a source of pollinators, biological control organisms, and of plant residues to help improve soil quality. The Ahupua'a approach, currently being used to restore some degraded watersheds (Campbell and Campbell, 2017), also facilitates the adoption of integrated crop-livestock or crop-aquaculture systems, as an integrated and resilient approach of land, nutrient and water management (Costa-Pierce, 2022; Farrant et al., 2021). A recent analysis indicates that community involvement at the watershed level, as observed in current restoration projects (Campbell and Campbell, 2017), is important to protect biodiversity and food security, and explores the benefits of traditional and community-based approaches for their management (Roberts and Sweeney, 2022).

4.3.6. Institutional and structural changes are needed to promote Agroecology

Structural and institutional changes are required to facilitate the transition and promotion of agroecology in Hawaii. Structural barriers were highlighted as part of a study that evaluated the adoption and performance of agroforestry systems in Hawaii. These barriers included systems to access land and capital, regulatory agencies, "other support institutions," a lack of institutional recognition for the value of local and indigenous knowledge, as well as a lack of available technical information (Hastings et al., 2022). Until now, the economic and power structure in the state, in the form of business and financial institutions and by the state and educational institutions have supported an economic model dependent on tourism, the military, and on a plantation-based economy, which has been engrained since statehood.

As a result of social and peasant movements in Ecuador, support for agroecology, including needed institutional changes, were included as part of Constitutional Amendments in 2009. Article 14 of the amended constitution states that "The State shall stimulate agroecological, organic and sustainable production by way of promotion, training programs, special lines of credit, and commercialization mechanisms within both the internal and external markets, among other measures. Public purchasing programs shall give priority to associations of agroecological producers" (Intriago et al., 2017).

4.3.7. Institutional changes needed in Higher Education to Support Research and Educational on Agroecology

Funding research and development of sustainable agricultural systems and practices can improve yield and efficiency while reducing environmental impacts. This can be achieved through public funding of research projects, educational and training programs for farmers, and incentives for the development of sustainable technology. The University system in the state, should be encouraged to develop formal undergraduate degrees on organic farming and agroecology. Additional structural changes in academia include the breaking of disciplinary barriers to promote more interdisciplinary work in terms of research and instructional programs, as well as changing the incentives and professional promotion programs, to encourage research that supports the local agricultural industries. In summary, educational institutions should commit considerable efforts and resources to assist the agricultural industries towards the transition and conversion to agroecology (DeLonge et al., 2016; UCS, 2015). In addition, educational institutions at all levels should adopt agroecology and indigenous knowledge as an integral part of their agricultural instruction, service, and research programs.

4.3.8. Regulate corporate agriculture

Regulations can help protect health and environmental risks posed by corporate agriculture. Policies that require transparency of food sources, protect animal welfare, and penalize unsustainable practices, can promote a shift toward sustainable and organic farming.

4.3.9. Upscale (expand) or popularize agroecology by learning from existing model organic or agroecological farms in the state.

The Food and Agriculture Organization (FAO) of the United Nations outlines that the upscaling of agroecology is a pathway to transform the food system and to achieve the United Nations Sustainable Development goals (SDGs) (Schwarz et al., 2022). Along with technical information provided by the University extension service, the farmer-to-farmer approach of technology dissemination is an effective way to pass along information about new and alternative production methods. However, building social capital (Pretty, 2020), along with comprehensive community-based and participatory educational programs will be required to share the holistic and socially responsible concepts of agroecology. Community farmer groups, or associations can also be effective in helping to formulate the agroecological concepts and practices that are the most appropriate for their particular community. It is also possible to learn from the experience with particular crops, to develop educational and farm outreach agroecological programs (Smith et al., 2009).

4.3.10. Community Organization

The promotion and success of agroecology programs depend, by enlarge, on community organization and organizational capacity, which is necessary to challenge the prevailing government policies, institutional values, and mainstream academic programs, that will lead to the support of small family farms, and for a transformation of the food system– in other words, the opportunity of community groups to have a seat at the table, when discussing policy issues, and research agendas, that will have an impact on the future of agriculture in the state. An organizational structure is also required to disseminate, from farm to farm, the value of adopting agroecological farming techniques which will lead to the upscaling and adoption of agroecology at a regional level. Due to the grass-root nature of the agroecological movement, the horizontal transfer of knowledge, between farmers, and among communities in the form of farmer-to-farmer exchanges, or farm schools, has been a central determinant for the success of agroecology adoption in many countries (Akanmu et al., 2023). The goal of a strong organizational structure, referred to as 'organicity' by social movements, is thus to challenge current agricultural policies and also to have a multiplier effect for the dissemination of agroecological practices (Rosset and Altieri, 2017; Intriago eg al., 2017).

4.4. Integrated Food Policy Recommendations

4.4.1. Public Policy:

Community-based agricultural development programs can be promoted by state public and educational agencies in partnership with private interests, to promote an agroecological model of production in Hawaii. Public Policy goals to promote an agroecological model of agricultural production in Hawaii include,

i) Restore and maintain soil fertility in production areas that have experienced historical high levels of soil erosion, pesticide contamination, and degradation of soil quality and fertility.

ii) Develop resilient production systems that can better withstand the imminent impacts of climate change in the form of increased periodic droughts and flooding events, and warmer temperatures.

iii) Develop resilient communities and local food production and marketing systems (marketing chains), to improve food self-sufficiency in the state.

iv) Develop participatory community-based farming systems and marketing channels that reflect their indigenous, ethnic, and cultural values– and to improve community food security and sovereignty, to protect their environment and traditional life-styles.

4.4.2. Meeting the 2030 UN Sustainable Development Goals and in line with the Hawaii 2050 Sustainability Plan

Agroecology is increasingly being recognized for its potential to help reach the United Nations. Sustainability Development Goals (Kerr, 2020; Schwarz et al., 2022; Akanmu et al., 2023)

- SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
- SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
- SDG 12: Ensure sustainable consumption and production patterns
- SDG 13: Take urgent action to combat climate change and its impacts.
- SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- SDG 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

4.4.3. Metrics:

a. Ecological

- Number of farms that have adopted agroecological farming systems
- Acreage in the state under agroecological farming management
- Number of farming communities that have adopted or incorporated agroecological farming systems
- Establishment of undergraduate degrees and graduate programs on organic farming and agroecology at the University level.

- Establish key sustainability and ecological indicators (such as activity of earthworms, pollinators, and native species), to assess progress in the ecological health of farming systems and surrounding green corridors.
- Number of peer reviewed publications on the agroecological production of high value and resilient food crops in Hawaii

b. Economic

- Number of public and private food service businesses that have incorporated agroecological principles (including organic), and products into the production chain.
- Dollar value of agroecological products marketed in the state
- Number of agroecological branded products used as marketing branding strategies
- Number of economic analysis studies to foster the adoption and growth of agroecological farming and marketing in the state.
- Establishment of marketing chains for the direct-market distribution of agroecological produce in all key agricultural regions of the state.

c. Sociocultural

- Number of farming communities, bioregions, or ahupua'a that have adopted agroecological farming principles
- Number of communities that have adopted agroecological principles as part of their long-term planning goals.
- Number of communities that have adopted increased local-food production systems to improve food security and sovereignty.
- Establishment of ahupua'a-based community seed banks (consisting of the identification and preservation of adapted germplasm) as part of a statewide Public Seed Initiative.
- Increased access to informal and formal educational opportunities to learn about agroecological farming and marketing practices

d. Governance

- Adopt agroecology implementation policies at the City, County, Island, and state level
- Land use policies are adjusted to facilitate adoption of small-scale agroecological production
- Aspects of social justice, food security, food sovereignty, and gender-equality are incorporated as part of the promotion and adoption of agroecology.
- The Ahupua'a concept of watershed management is incorporated to manage natural resources and nutrient cycles.
- Educational institutions commit considerable efforts and resources to assist the agricultural industries towards the transition and conversion to agroecology (DeLonge et al., 2016; UCS, 2015)
- Educational institutions at all levels adopt agroecology and indigenous knowledge as an integral part of their agricultural instruction, service, and research programs.

5.0. Success stories from the adoption of agroecology

Over the past thirty years, success stories have been observed, from the adoption of agroecology, that have led to improved resilience, productivity and well-being of small-scale farmers and rural communities in many parts of the world. Institutionally, the United Nations Food and Agriculture Organization (FAO), along with several governments, and universities have incorporated agroecology into their programmatic activities. Community groups and agroecologists, however, need to remain cognizant of the efforts to co-opt the concept of agroecology, by business interests and proponents of the so-called “Green Revolution” as they purport to support “sustainability,” and adaptation to climate change– within the production and business framework of Industrial or Conventional agriculture (Rosset and Altieri, 2017). Some of the benefits that result from the adoption of agroecology are presented in Table 3. Some of the success stories that have been experienced at a national or regional level, are presented in Table 4.

Table 3. Some of the reported benefits from the adoption of agroecology or organic farming practices

Benefits from adoption	References
Increased profitability	Crowder and Reganold, 2015; Reganold and Wachter, 2016; Pimentel et al., 2005
Comparable yields and pest control	Crowder et al., 2010; Delate et al., 2013; Zehnder et al., 2007
Improved water use efficiency and drought tolerance	Wheeler et al., 2015; Pimentel et al., 2005
Improved soil quality and organic matter content	Delate et al., 2013; Pimentel et al., 2005
Increased nitrogen mineralization and soil microbial activity	Wheeler et al., 2015
Improved biodiversity, ecosystem services and system resilience at farm and landscape levels	Gomiero et al., 2011; Reganold and Wachter, 2016; Petit et al., 2015; Tiemann et al., 2015
Improved Sustainability Index (SI)	Heinemann et al., 2014; Priego-Castillo et al., 2009
Improved pest biocontrol	Crowder et al., 2010; Zehnder et al., 2007
Reduced pesticide levels in the body, including on children	Reganold and Wachter, 2016; Barański et al., 2014; Benbrook and Baker, 2014; Magnér et al., 2015; Bradman et al., 2015

Table 4. Success stories from the adoption of agroecological practices. For a number of case studies also see, Via Campesina (2015).

Success story	Regions	References
Regional adoption and dissemination, and introduction of academic and field-based programs	France, Spain, India, Latin America	Toledo, 2023
FAO Congress in Agroecology, 2014 & 2018, with a call for upscaling of agroecology	Global	Toledo, 2023
Adoption by 2.3 million small farmers, on 7.8 million hectares, including 18,000 agroecology learning communities, and programs at 55 universities	Mexico	Toledo, 2023
Traditional farmers following agroecological practices have fed large sectors of the global population for centuries, and continue to do so (such as 75 million traditional small-scale rice farmers in China, today).	Global, China	Rosset and Altieri, 2017; Akanmu et al., 2023
Agroecology projects in 20 countries of Africa on 12.7 million hectares with over 10 million farmers led to over 2x yield increases, and improved farming practices	Africa	Akanmu et al., 2023
Agroforestry projects in several countries of Africa led to increased corn yields as compared to monocultures; In Niger, a corn-Faidherbia based agroforestry system was adopted on 4.8 million hectares, improving resilience and leading to its dissemination to nearby countries.	Africa	Akanmu et al., 2023, Rosset and Altieri, 2017
Agroecology adoption, Asia, >2.8 million households, on over 4.9 million Hectares, improved productivity	Asia	Rosset and Altieri, 2017;
Zero Budget Natural Farming (ZBNF), adoption by >100,000 farmers, increased yields, soil conservation and seed diversity	Southern India	Rosset and Altieri, 2017;
Agroecology projects Latin America, >100,000 farming families, >120,000 Ha, increased yields and resource use efficiency; Brazil > 1 mn Ha.	Latin America	Rosset and Altieri, 2017; Altieri & von der Weid, 2012.
Evaluation of 286 alternative agriculture projects on 57 countries, on 27 million hectares showed average increased yields of 79% (practices included diversification for pest control, legumes for nitrogen fixation, conservation tillage, agroforestry, aquaculture, and crop-livestock integrated systems).	Global south, inc. Asia and Latin America	Pretty, 2006

6.0. References

Adeoye, I.B., 2020. Factors affecting efficiency of vegetable production in Nigeria: A review. pp.1-14. In: Ifeoluwapo O. Amao and Iyabo B. Adeoye (Eds.) Agricultural Economics, 1, IntechOpen. DOI: 10.5772/intechopen.92702

Adrian Jr, J.L., Upshaw, C. and Mook, R., 1989. Evaluation of feasibility of fruit and vegetable crops using market window analysis. Journal of Food Distribution Research, 20(856-2016-56299),142-152.

African Center for Biodiversity. 2016. Soil fertility: Agro-ecology and not the green revolution for Africa. Melville, Johannesburg, South Africa. 21 pp.

Akanmu, A.O., Akol, A.M., Ndolo, D.O., Kutu, F.R. and Babalola, O.O. 2023. Agroecological techniques: Adoption of safe and sustainable agricultural practices among the smallholder farmers in Africa. Frontiers in Sustainable Food Systems, 7, 1143061. DOI 10.3389/fsufs.2023.1143061

Altieri, M.A., 1987. Agroecology: the scientific basis of alternative agriculture. Westview Press. Boulder, CO. 226 pg.

Altonn, Helen. 2003. Most of state suffering from low rainfall. Honolulu Star-Bulletin. Aug. 9, 2003.

Altieri, M. and von der Weid, J.M., 2012. Prospects for agroecologically based natural-resource management for low-income farmers in the 21st century. Concept paper. NGOC/CGIAR.

Barański, M.; Średnicka-Tober, D.; Volakakis, N.; Seal, C.; Sanderson, R.; Stewart, G.B.; Benbrook, C.; Biavati, B.; Markellou, E.; Giotis, C.; Gromadzka-Ostrowska, J. 2014. Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses. British J. Nutr. 112 (5), 794-811. doi:10.1017/S0007114514001366

Beamer, K., Tuma, A., Thorenz, A., Boldoczki, S., Kotubetey, K., Kukea-Shultz, K. and Elkington, K., 2021. Reflections on Sustainability Concepts: Aloha Āina and the Circular Economy. Sustainability 2021, 13, 2984. https://doi.org/10.3390/su13052984

Beamer, K., K. Elkington, P. Souza, A. Tuma, A. Thorenz, S. Köhler, K. Kukea-Shultz, K. Kotubetey, and K. B. Winter. 2023. Island and Indigenous systems of circularity: how Hawai‘i can inform the development of universal circular economy policy goals. Ecology and Society 28(1):9. https://doi.org/10.5751/ES-13656-280109

Benbrook, C.M.; Baker, B.P. Perspective on dietary risk assessment of pesticide residues in organic food. Sustainability 2014, 6(6), 3552-3570. doi:10.3390/su6063552

Berning, E.H., Andersen, C.V.H., Mertz, O., Dickinson, N., Opgenorth, M., Lincoln, N.K., Rashford, J.H. and Rønsted, N., 2022. Resilience of breadfruit agro-ecosystems in Hawaiʻi during the COVID-19 pandemic. CABI Agriculture and Bioscience, 3(1), 56. https://doi.org/10.1186/s43170-022-00125-3

Bezner Kerr, R., Liebert, J., Kansanga, M. and Kpienbaareh, D., 2022. Human and social values in agroecology: A review. Elem Sci Anth, 10, 1 DOI: https://doi.org/10.1525/ elementa.2021.00090

Blandon, S. and Falk, C.L., 2012. Market Window Analysis for Selected Vegetables for Southern New Mexico. NM State University, Agricultural Experiment Station. Research Report 775. 8 pp. https://pubs.nmsu.edu/research/horticulture/RR775.pdf

Bonaudo, T., Bendahan, A.B., Sabatier, R., Ryschawy, J., Bellon, S., Leger, F., Magda, D. and Tichit, M., 2014. Agroecological principles for the redesign of integrated crop–livestock systems. European Journal of Agronomy, 57, 43-51.

Borenstein, Seth. 2023. Earth is 'really quite sick now' and in danger zone in nearly all ecological ways, study says. Associated Press. May 31, 2023. https://apnews.com/article/earth-environment-climate-change-nature-sick-2dded06915af4645253f5c29abff4794

Bradman, A.; Quirós-Alcalá, L.; Castorina, R.; Schall, R.A.; Camacho, J.; Holland, N.T.; Barr, D.B.; Eskenazi, B. 2015. Effect of organic diet intervention on pesticide exposures in young children living in low-income urban and agricultural communities. Environ. Health Persp. 123(10), 1086-1093. http://dx.doi.org/10.1289/ehp.1408660.

Campbell, H.V. and Campbell, A.M., 2017. Community-Based Watershed Restoration in He 'eia (He 'eia Ahupua 'a), O 'ahu, Hawaiian Islands. Case studies in the environment, 1, 1-17, DOI: https://doi.org/./cse..sc.

Cardillo, C. and Cimino, O., 2022. Small Farms in Italy: What Is Their Impact on the Sustainability of Rural Areas?. Land, 11(12), 2142. https://doi.org/10.3390/land11122142

Carpenter, S.J. 1994. Farm chemicals, soil erosion, and sustainable agriculture. Stanford Environmental Law Journal, Stan. Envtl. L.J. 13,190-243

Chancellor, Chris. 2019. More farmers, better food: Why and how to put small-scale sustainable producers at the core of the new CAP. Nyéléni: Europe and Central Asia. 32 pp.

Comerford, Nick. 2020. Former Dean of the College of Tropical Agriculture and Human Resources, indicated that high-tech greenhouse operations were the future of agriculture in Hawaii. Pers. Communication. Feb. 26, 2020.

Costa-Pierce, B.A., 2022. The anthropology of aquaculture. Frontiers in Sustainable Food Systems, 6, p.843743. doi: 10.3389/fsufs.2022.843743

Crowder, D. W., and Reganold, J. P. 2015. Financial competitiveness of organic agriculture on a global scale. Proceedings of the National Academy of Sciences,112(24):7611-7616. www.pnas.org/cgi/doi/10.1073/pnas.1423674112

Crowder D.W.; Northfield T.D.; Strand M.R.; Snyder W.E. 2010. Organic agriculture promotes evenness and natural pest control. Nature 466(7302), 109-112.

Delate K.; Cambardella, C.; Chase, C.; Johanns, A.; Turnbull, R. 2013. The long-term agroecological research (LTAR) experiment supports organic yields, soil quality, and economic performance in Iowa. Crop Management 12(1) doi:10.1094/CM-2013-0429-02-RS

DeLonge, M.S., Miles, A. and Carlisle, L., 2016. Investing in the transition to sustainable agriculture. Environmental Science & Policy, 55, 266-273, http://dx.doi.org/10.1016/j.envsci.2015.09.013

De Molina, M. and Lopez-Garcia, D., 2021. Principles for designing Agroecology-based Local (territorial) Agri-food Systems: A critical revision. Agroecology and Sustainable Food Systems, 45(7), 1050-1082. https://doi.org/10.1080/21683565.2021.1913690

Department of Business Economic Development & Tourism (DBEEDT). 2012. Report: Increased food security and food self-sufficiency strategy. Office of Planning, DBEEDT, Honolulu, HI. 59 pp.

Donham, J. and Wezel, A,. 2022. 10 Steps to achieve the European green deal. Policy Brief. Agroecology for Europe, AE4EU.June 2022. 10 pp. www.ae4eu.eu

Donham, J., A. Wezel, Paola Migliorini. 2022. Improving eco-schemes in the light of agroecology: Key recommendations for the 2023-2027 Common Agricultural Policy. Policy Brief. Agroecology for Europe, AE4EU. February 2022. 10 pp. www.ae4eu.eu

Drinkwater, L.E. and Snapp, S.S. 2007. Nutrients in Agroecosystems: Rethinking the Management Paradigm. Advances in Agronomy. Advances in Agronomy, 92: 163–186. DOI: 10.1016/S0065-2113(04)92003-2

Duffy, D.J. and Lepczyk, C.A., 2021. The Historical Ecology of Game Species Introductions in Hawai ʻi. Pacific Science, 75 (1), 1-41. https://doi.org/10.2984/75.1.1

Edwards, M.H., Shjegstad, S.M., Wilkens, R., King, J.C., Carton, G., Bala, D., Bingham, B., Bissonnette, M.C., Briggs, C., Bruso, N.S. and Camilli, R., 2016. The Hawaii undersea military munitions assessment. Deep Sea Research Part II: Topical Studies in Oceanography, 128, 4-13. http://dx.doi.org/10.1016/j.dsr2.2016.04.011

Ehrlich, P.R. and Harte, J., 2015. To feed the world in 2050 will require a global revolution. Proceedings of the National Academy of Sciences, 112(48), 14743-14744. www.pnas.org/cgi/doi/10.1073/pnas.1519841112

European Coordination Via Campesina (ECVC). 2021. Training repository: Promoting peasant agroecology. Peasants to peasants, an agro-ecological training framework. European Erasmu+ Program. France. 20 pp.

Farrant, D.N., Frank, K.L. and Larsen, A.E., 2021. Reuse and recycle: Integrating aquaculture and agricultural systems to increase production and reduce nutrient pollution. Science of the total environment, 785,146859. https://doi.org/10.1016/j.scitotenv.2021.146859

Francis, C.A. and P. Porter. 2011. Ecology in Sustainable Agriculture Practices and Systems, Critical Reviews in Plant Sciences, 30:1-2, 64-73, http://dx.doi.org/10.1080/07352689.2011.554353

Ghazal, K.A., Leta, O.T., El-Kadi, A.I. and Dulai, H., 2019. Assessment of wetland restoration and climate change impacts on water balance components of the Heeia Coastal wetland in Hawaii. Hydrology, 6(2), 37. https://doi.org/10.3390/hydrology6020037

Gomiero, T.; Pimentel, D.; Paoletti, M.G. 2011. Is there a need for a more sustainable agriculture?, CRC Crit. Rev. Plant Sci. 30 (1-2), 6-23. http://dx.doi.org/10.1080/07352689.2011.553515

Gon III, Sam ʻOhu and Winter, K.B., 2019. A Hawaiian Renaissance That Could Save the World: This archipelago's society before Western contact developed a large, self-sufficient population, yet imposed a remarkably small ecological footprint. American Scientist, 107 (4), 232-240, DOI: 10.1511/2019.107.4.232

Gon III, S.M., Tom, S.L. and Woodside, U., 2018. ʻĀina Momona, Honua Au Loli-Productive Lands, Changing World: Using the Hawaiian Footprint to Inform Biocultural Restoration and Future Sustainability in Hawai ʻi. Sustainability, 10 (10), 3420. doi:10.3390/su10103420

Guareschi, M., Maccari, M., Sciurano, J.P., Arfini, F. and Pronti, A., 2020. A methodological approach to upscale toward an agroecology system in EU-LAFSs: the case of the Parma Bio-District. Sustainability, 12 (13), 5398. doi:10.3390/su12135398

Gupta, C., 2014. Sustainability, self-reliance and Aloha Aina: the case of Molokai, Hawai'i. International Journal of Sustainable Development & World Ecology, 21(5), 389-397. http://dx.doi.org/10.1080/13504509.2014.880163

Gupta, J., Liverman, D., Prodani, K., Aldunce, P., Bai, X., Broadgate, W., Ciobanu, D., Gifford, L., Gordon, C., Hurlbert, M. Inoue, C.Y., et al. 2023. Earth system justice needed to identify and live within Earth system boundaries. Nature Sustainability, 1-9, https://doi.org/10.1038/s41893-023-01064-1

Hamakua Agricultural Plan. 2006. County of Hawaii Planning Department. Hilo, HI. 41 pp.

Haji, J. and Andersson, H., 2006. Determinants of efficiency of vegetable production in smallholder farms: The case of Ethiopia. Acta Agriculturae Scand Section C, 3 (3-4), 125-137. https://doi.org/10.1080/16507540601127714

Hastings, Z., Wong, M. and Ticktin, T., 2021. Who Gets to Adopt? Contested Values Constrain Just Transitions to Agroforestry. Frontiers in Sustainable Food Systems, 5, 727579. doi: 10.3389/fsufs.2021.727579

Hayes, T.B. and Hansen, M., 2017. From silent spring to silent night: Agrochemicals and the anthropocene. Elementa: Science of the Anthropocene, 5, 57, DOI: https://doi.org/10.1525/elementa.246

Heinemann, J.A.; Massaro, M.; Coray, D.S.; Agapito-Tenfen, S.Z.; Wen, J.D. 2014. Sustainability and innovation in staple crop production in the US Midwest. Int. J. Agr. Sustain. 12(1), 71-88. DOI:10.1080/14735903.2013.806408

HLPE. 2019. Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Report No. 14, CA5602EN/1/07.19, FAO, Rome, 163 pp.

Holt-Giménez, E., Shattuck, A. and Van Lammeren, I., 2021. Thresholds of resistance: agroecology, resilience and the agrarian question. The Journal of Peasant Studies, 48 (4), 715-733, DOI: 10.1080/03066150.2020.1847090

Huambachano, M. A. 2019. Indigenous food sovereignty. N. Z. J. Ecol. 43, 1-6. doi: 10.20417/nzjecol.43.39

IFAD-UNEP, United Nations Environment Program. 2013. Smallholders, food security and the environment. Rome: International Fund for Agricultural Development Rome, Italy, 56 pp.

Intriago, R., Gortaire Amézcua, R., Bravo, E. and O'Connell, C., 2017. Agroecology in Ecuador: historical processes, achievements, and challenges. Agroecology and Sustainable Food Systems, 41 (3-4), 311-328. https://doi.org/10.1080/21683565.2017.1284174

Jarvis, D.I.; Hodgkin, T.; Sthapit, B.R.; Fadda, C.; Lopez-Noriega, I. An heuristic framework for identifying multiple ways of supporting the conservation and use of traditional crop varieties within the agricultural production system. Crit. Rev. Plant Sci. 2011, 30, 125–176.

Jolly, D. 1999. Jolly, D., 2012. Agricultural policies and the future of US family farming. Univ. California Small Farm Program. Davis, Calif.

Kagawa-Viviani, A., Levin, P., Johnston, E., Ooka, J., Baker, J., Kantar, M. and Lincoln, N.K., 2018. I ke ēwe ʻāina o ke kupuna: Hawaiian ancestral crops in perspective. Sustainability, 10(12), 4607. doi:10.3390/su10124607

Keala, G., Hollyer, J.R., and Castro, L. 2007. Loko iʻa: A manual on Hawaiian fishpond restoration and management. College of Tropical Agriculture and Human Resources, University of Hawaiʻi at Manoa, Honolulu. 76 pp.

Kerr, R.B., 2020. Agroecology as a means to transform the food system. J Sustainable Organic Agric Syst, Landbauforschung, 70, 77-82. DOI:10.3220/LBF1608651010000

Kohala Center. 2011. Moving Together into the Future: An Agricultural Renaissance in Hawaiʻi. The Kohala Center. Hawaiʻi Island. Jan. 27, 2011.

Kohala Center, 2012. Health Impact Assessment 2010, Hawaiʻi County Agriculture Development Plan. Kohala Center, Kamuela, Hawaii. 108 pp.

Kremen, C. and Miles, A., 2012. Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. Ecology and society, 17(4), 40. http://dx.doi. org/10.5751/ES-05035-170440

Kubota, Gary T. 2010. Dry conditions leave isle farms parched. Honolulu Star Adv. July 26, 2010.

Kurashima, N., Fortini, L. and Ticktin, T., 2019. The potential of indigenous agricultural food production under climate change in Hawaiʻi. Nature Sustainability, 2(3),191-199. https://doi.org/10.1038/s41893-019-0226-1

La Croix, S. and Mak, J., 2021. Reviving Agriculture to Diversify Hawaii's Economy. University of Hawaii at Manoa, University of Hawaii at Manoa Economic Research Organization, UHERO Research Brief, 21, Honolulu, HI, 19 pp.

Leakey, R.R., 2014. The role of trees in agroecology and sustainable agriculture in the tropics. Annual review of phytopathology, 52, 113-133, doi: 10.1146/annurev-phyto-102313-045838

Lincoln, Mileka. 2016. Ige wants to double local food production by 2030 ("Gov. David Ige pledged to double local food production by 2030"). Hawaii News Now. Sept. 2, 2016.

Lincoln, N.K., 2020. Agroforestry form and ecological adaptation in ancient Hawai'i: extent of the pākukui swidden system of Hāmākua, Hawai'i Island. Agricultural Systems, 181, 102808. https://doi.org/10.1016/j.agsy.2020.102808

Lincoln, N. and Ladefoged, T., 2014. Agroecology of pre-contact Hawaiian dryland farming: the spatial extent, yield and social impact of Hawaiian breadfruit groves in Kona, Hawai'i. Journal of Archaeological Science, 49, 192-202, http://dx.doi.org/10.1016/j.jas.2014.05.008

Lincoln, N.K., Haensel, T.P. and Lee. 2023. Modeling Hawaiian Agroecology: Depicting traditional adaptation to the world's most diverse environment. Front. Sustain. Food Syst. 7:1116929. doi: 10.3389/fsufs.2023.1116929

López-García, D. and González de Molina, M., 2021. An operational approach to agroecology-based local agri-food systems. Sustainability, 13(15), 8443. https://doi.org/10.3390/su13158443

Madson, A., Dimson, M., Fortini, L.B., Kawelo, K., Ticktin, T., Keir, M., Dong, C., Ma, Z., Beilman, D.W., Kay, K. and Ocón, J.P., 2023. A near four-decade time series shows the Hawaiian Islands have been browning since the 1980s. Environmental Management, 71(5), 965-980. https://doi.org/10.1007/s00267-022-01749-x

Magnér, J.; Wallberg, P.; Sandberg, J.; Cousins, A.P. 2015; Human exposure to pesticides from food. Publisher: Swedish Environmental Research Institute. Report No. U 5080, Consulté le., Stockholm, Sweden, 3(06), 2015

Mottram, A., Carlberg, E., Love, A., Cole, T., Brush, W., and Lancaster, B. 2017. Resilience Design in Smallholder Farming Systems: A Practical Approach to Strengthening Farmer Resilience to Shocks and Stresses. Washington, DC: The TOPS Program and Mercy Corps. Washington D.C. 121 pp.

NASS. USDA-National Agricultural Statistics Service. 2021. News Release: Family-owned farms account for 93% of Hawaii farms, according to the 2017 Census of Agriculture Typology Report. Feb. 8, 2021. Honolulu, HI.

National Research Council (NRC), 1989. Alternative agriculture The National Academies Press: Washington, DC,USA, 464 pp. https://doi.org/10.17226/1208.

National Research Council (NRC), 2002. Publicly funded agricultural research and the changing structure of US agriculture. Washington, DC, The National Academies Press. https://doi.org/10.17226/10211.

North Kohala Community Development Plan. 2008. The County of Hawaii Planning Dept. Hilo, HI. Nov. 5, 2008, 134 pp.

Odum, E.P. 1953. Fundamentals of Ecology. W.B. Saunders Co. Philadelphia. 384 pp.

Office of Planning and Sustainable Development (OPSD). 2018. Hawai‘i 2050 Sustainability Plan - Ten Year Measurement Update. State of Hawaii Office of the Auditor. Honolulu. March 7, 2018. 160 pp.

Peano, C. and Sottile, F., 2017. Agroecology as a challenge for the competitiveness of small scale agriculture. Italus Hortus, 24(3), 1-14. doi: 10.26353/j.itahort/2017.3.114

Petit, S.; Munier-Jolain, N.; Bretagnolle, V.; Bockstaller, C.; Gaba, S.; Cordeau, S., Lechenet, M.; Mézière, D.; Colbach, N. Ecological intensification through pesticide reduction: weed control, weed biodiversity and sustainability in arable farming. Environmental Management 2015, 56(5), 1078-90. DOI: 10.1007/s00267-015-0554-5

Pimentel, D. 2011. Food for Thought: A Review of the Role of Energy in Current and Evolving Agriculture, Critical Reviews in Plant Sciences, 30:1-2, 35-44. http://dx.doi.org/10.1080/07352689.2011.554349

Pimentel, D.; Hepperly, P.; Hanson, J.; Douds, D.; Seidel, R. 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience 55(7), 573-582.

Ponisio, L.C. and Ehrlich, P.R., 2016. Diversification, yield and a new agricultural revolution: Problems and prospects. Sustainability, 8(11), 1118. doi:10.3390/su8111118

Pretty, J. N., Noble, A. D., Bossio, D., Dixon, J., Hine, R. E., Penning de Vries, F. W., & Morison, J. I. 2006. Resource-conserving agriculture increases yields in developing countries. Environmental science & technology, 40 (4), 1114-1119. 10.1021/es051670d

Pretty, J., 2020. The agroecology of redesign. J. Sustain. Org. Agric. Syst, 70(2), 25-30. DOI:10.3220/LBF1605102089000

Priego-Castillo, GA.; Galmiche-Tejeda, A.; Castelán-Estrada, M.; Ruiz-Rosado, O.; Ortiz-Ceballos, A. 2009. Evaluación de la sustentabilidad de dos sistemas de producción de cacao: estudios de caso de unidades de producción rural en Comalcalco, Tabasco. Universidad y Ciencia 25(1), 39-57

Reganold, J.P.; Wachter, J.M. 2016. Organic agriculture in the twenty-first century. Nature Plants, 15221. doi:10.1038/nplants.2015.221

Rehman, A., Farooq, M., Lee, D.J. and Siddique, K.H., 2022. Sustainable agricultural practices for food security and ecosystem services. Environmental Science and Pollution Research, 29, 84076-84095, https://doi.org/10.1007/s11356-022-23635-z

Ricciardi, V., Mehrabi, Z., Wittman, H., James, D. and Ramankutty, N., 2021. Higher yields and more biodiversity on smaller farms. Nature Sustainability, 4(7), 651-657. https://doi.org/10.1038/s41893-021-00699-2

Roberts, N., Sweeney, S. and Li, C., 2022. YL Blog# 31– Community-based Watershed Management for Socio-Cultural Benefits in Hawai ʻi. Pacific Forum, Honolulu, HI. Sept. 21, 2022.

Rocha, C., Burlandy, L. and Maluf, R., 2012. Small farms and sustainable rural development for food security: The Brazilian experience. Development Southern Africa, 29(4), 519-529. https://doi.org/10.1080/0376835X.2012.715438

Rosset, P.M. and Altieri, M.A. 2017. Agroecology: science and politics. Practical Action Publishing. Black Point, Nova Scotia, Canada, ISBN 978-1-55266-975-4, 162 pp.

Sayer, J., & Cassman, K. G. 2013. Agricultural innovation to protect the environment. Proceedings of the National Academy of Sciences, 110(21), 8345-8348. www.pnas.org/cgi/doi/10.1073/pnas.1208054110

Schwarz, G., Vanni, F., Miller, D., Helin, J., Pražan, J., Albanito, F., Fratila, M., Galioto, F., Gava, O., Irvine, K. and Landert, J., 2022. Exploring sustainability implications of transitions to agroecology: a transdisciplinary perspective. EuroChoices, 21(3), 37-47. DOI: 10.1111/1746-692X.12377

Shirota, L.M. 2021. 48% of Hawaiʻi families with children report food insecurity. University of Hawaiʻi at Mānoa. Social Sciences, Dean's Office. UHM News, March 25, 2021, https://manoa.hawaii.edu/news/article.php?aId=11241

Sirabis, W.C., Kantar, M.B., Radovich, T. and Lincoln, N.K., 2022. Nitrogen Dynamics and Sweet Potato Production under Indigenous Soil Moisture Conservation Practices in the Leeward Kohala Field System, Hawai'i Island. Soil Systems, 6(1), 16. https://doi.org/10.3390/ soilsystems6010016

Smith, G.K., Gering, E., Guerrero, R.F., McTavish, E.J. and Lydgate, T., 2009. *Theobroma cacao* L.(Malvaceae) agroecology in Kauai: A case study. Pac. Agric. Nat. Resour. 1, 21-26

Snapp S, Kebede Y, Wollenberg E, Dittmer KM, Brickman S, Egler C, Shelton S. 2021. Agroecology and climate change rapid evidence review: Performance of agroecological approaches in low- and middle- income countries. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Sproat, D., and Palau-McDonald, M. M. 2022. The duty to aloha 'aina: indigenous values as legal foundation for Hawai'i's public trust. Harvard Civil Rights-Civil Liberties Law Review, 57(2), 525-576.

Stupplebeen, D.A., 2019. Peer Reviewed: Housing and Food Insecurity and Chronic Disease Among Three Racial Groups in Hawai'i. Preventing Chronic Disease, Vol. 16, E13, Centers for Disease Control and Prevention, 11 pp. DOI: http://dx.doi.org/10.5888/pcd16.180311external icon.

Tiemann, L.K.; Grandy, A.S.; Atkinson, E.E.; Marin-Spiotta, E.; McDaniel, M.D. Crop rotational diversity enhances belowground communities and functions in an agroecosystem. Ecol. Lett. 2015, 18, 761–771. doi: 10.1111/ele.12453

Toledo, V.M. 2023. El escalamiento de la agroecología en México. Op-ed. La Jornada, Mexico City. June 6, 2023. https://www.jornada.com.mx/2023/06/06/opinion/014a1pol

UCS, Union of Concerned Scientists, 2015. Counting On Agroecology: Why We Should Invest More in the Transition to Sustainable Agriculture. Union of Concerned Scientists. Fact-sheet. Nov. 2015. 6 pp.

Valenzuela, H.R. 1992. Hawaii can break new ground in agriculture. Honolulu Star-Bulletin. Editorial. May 21, 1992. pg. A-11.

Valenzuela, H. 2009. Diversified ag gets only lip service. Op-editorial. Honolulu Advertiser. June 29, 2009.

Valenzuela, H. 2015. Pest and Disease Control Strategies for Sustainable Pacific Agroecosystem. In Elevitch, C.R. (Ed.) Agroforestry Landscapes for Pacific Islands: Creating abundant and resilient food systems. Publisher: Permanent Agriculture Resources (PAR), 2015, Kona, Hawaii Island. pp. 332. Available online:

Valenzuela, H. 2016. Agroecology: A Global Paradigm to Challenge Mainstream Industrial Agriculture. Horticulturae. 2(1), 2. doi:10.3390/horticulturae2010002, http://www.mdpi.com/2311-7524/2/1/2

Valenzuela, H.R. 2018. Pollinators and Sustainable Farming in Hawaii. Bee World. 95(4) 117-121. https://doi.org/10.1080/0005772X.2018.1507347

Valenzuela, H., 2023. Ecological Management of the Nitrogen Cycle in Organic Farms. Nitrogen, 4(1), 58-84, https://doi.org/10.3390/nitrogen4010006

Valenzuela, H.R. and J. DeFrank. 1995. Agroecology of tropical underground crops for small-scale agriculture. CRC Critical Review in Plant Sciences. 14, 213-238. https://doi.org/10.1080/07352689509701927.

Vermeulen, S. J., Challinor, A. J., Thornton, P. K., Campbell, B. M., Eriyagama, N., Vervoort, J. M., ... & Smith, D. R. (2013). Addressing uncertainty in adaptation planning for agriculture. Proceedings of the National Academy of Sciences, 110(21), 8357-8362. doi/10.1073/pnas.1219441110

Volkmer, H.L. ed., 1998. Time to Act: a Report of the USDA National commission on Small Farms. Miscellaneous Publication 1545, DIANE Publishing. 121 pp.

Via Campesina. 2015. Peasant agroecology for food sovereignty and mother earth: Experiences of La Via Campesina. La Via Campesina, Notebook No. 7, April 2015. Waterfalls-Harare, Zimbabwe, 71 pp.

Wezel, A.; Bellon, S.; Doré, T.; Francis, C.; Vallod, D.; David, C. 2009. Agroecology as a science, a movement and a practice. A review. Agron. Sustain. Dev. 29, 503–515, doi:10.1051/agro/2009004

Wheeler, S.A.; Zuo, A.; Loch, A. 2015. Watering the farm: Comparing organic and conventional irrigation water use in the Murray–Darling Basin, Australia. Ecological Economics 112, 78-85. http://dx.doi.org/10.1016/j.ecolecon.2015.02.019

Winter, K. B., N. K. Lincoln, F. Berkes, R. A. Alegado, N. Kurashima, K. L. Frank, P. Pascua, Y. M. Rii, F. Reppun, I. S. S. Knapp, … and R. J. Toonen. 2020. Ecomimicry in Indigenous resource management: optimizing ecosystem services to achieve resource abundance, with examples from Hawai‘i. Ecology and Society 25(2), 26. https://doi.org/10.5751/ES-11539-250226

Winter, K. B., M. Blaich Vaughan, N. Kurashima, L. Wann, E. Cadiz, A. Kawelo, M. Cypher, L. Kaluhiwa, and H. K. Springer. 2023. Indigenous stewardship through novel approaches to collaborative management in Hawai‘i. Ecology and Society 28(1), 26. https://doi. org/10.5751/ES-13662-280126

Witcombe, A.M., Tiemann, L.K., Chikowo, R. and Snapp, S.S., 2023. Diversifying with grain legumes amplifies carbon in management-sensitive soil organic carbon pools on smallholder farms. Agriculture, Ecosystems & Environment, 356, 108611. https://doi.org/10.1016/j.agee.2023.108611

Zehnder, G.; Gurr, G.M.; Kühne, S.; Wade, M.R.; Wratten, S.D.; Wyss, E. 2007. Arthropod pest management in organic crops. Annu. Rev. Entomol. 52, 57-80. https://doi.org/10.1146/annurev.ento.52.110405.091337