MALAMA `ĀINA: A CONVERSATION ABOUT MAUI'S FARMING FUTURE

A PROJECT OF THE MAUI TOMORROW FOUNDATION

Looking towards Iao Valley

Prepared for Maui Tomorrow Foundation, Inc.
March 8, 2016

Report by Permaculture Design International LLC

MAUI TOMORROW

This report was funded by MAUI TOMORROW FOUNDATION, Inc. as part of its on-going commitment to state of the art sustainable development and the maintenance of Maui's rural lifestyle.

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Cover illustration by Silvia Yordanova

***Aloha ` āina** - love and respect the land, make it yours and claim stewardship for it*

***Malama ` āina** - care for and nurture the land so it can give back all we need to sustain life for ourselves and our future generations*

-Puanani Rogers, Ho`okipa Network

Beloved Maui is at a crossroads. The January 2016 announcement by Alexander and Baldwin (A&B) that Hawaiian Commercial & Sugar (HC&S) will be ending their 36,000 acre sugarcane operation has flung the door wide open to a much-needed conversation regarding what the future of farming on Maui can truly be. It's an opportunity to invite all the stakeholders into this discussion with the spirit of aloha, and draw on our collective mana`o to consider how we will plan ahead to malama `āina - care for and nurture the land so it can sustain life for ourselves and future generations.

Maui now imports upwards of 90% of its food and energy, most of our building materials, and all of our textiles - a precarious reality for a remote island. We need many more living wage jobs, ample affordable housing, abundant and affordable local food, and clean water to provide for our 145,000 citizens and 2.6 million tourists annually.

Facing the future, we have choices - what will farming look like on Maui from this moment forward? This question is intimately tied to the wai, our precious water resources, and any answers must offer solutions that care for and restore watersheds.

Laguna Blanca, Argentina. Twelve years after transitioning to diversified regenerative farming. http://www.tompkinsconservation.org/farm_laguna_blanca.htm

MA'O Organic Farms Hawai`i Investment Ready Program http://social-impact.org/regional-programs/investment-ready-hawaii

The closure of the HC&S sugarcane enterprise is an opening to the next generation of diversified farm businesses. 32,400 acres of sugarcane plantation land owned by HC&S are in question, of which 27,000 acres are designated Important Agricultural Land, and receive tax and water benefits intended to help keep large tracts of contiguous farmland intact, and make farming more affordable. **Maui's farming future is tied to this land.**

What kinds of agriculture will benefit Maui's people moving forward? For 150 years Maui agriculture has been large-scale, mono-crop, chemical dependent, and export oriented. Can a new farming model bring both economic and biological benefits? The sugarcane era is officially ending this year - citizens of Maui are concerned about the loss of jobs for so many families, and want to see Maui's agricultural legacy continue.

This report is the start of a community conversation - bringing our diverse people and businesses together to find long-term solutions that are pono. With that in mind, there are many stories that need to be told, and conversations that need to take place. This report offers a window into abundant, resilient **regenerative agriculture,** a way forward that prioritizes food crops, livestock, diverse and profitable enterprises, and can build a whole farming economy that is just and environmentally sound.

The key points addressed will touch on these important questions :

- What kinds of crops will grow here well and profitably?
- Should we prioritize food crops over commodity crops, and why? Can we have both?
- How do we remediate contaminated soils and aquifers?

Portuguese sugar workers - 6,000 in 1913
https://en.wikipedia.org/wiki/Portuguese_immigration_to_

- Can we have diverse livestock operations and what would that look like?
- How many more jobs can we create with diversified regenerative agriculture?
- Does Maui have enough farmers for all these businesses?
- How can we assure long-term access to land for farmers?
- Can affordable housing be integrated into the design?
- Does regenerative agriculture use less water, and can some of that water be returned to East Maui watersheds?
- Can we and should we expand agritourism?
- What type of infrastructure do we have for “food hubs” - processing, creating value-added products, improving local distribution, and providing education for farmers?
- How can we bring all the stakeholders to the table, including A&B, in a transparent and meaningful way?
- Will A&B sell the 27,000 acres now designated as Important Agricultural Lands? If so, at what price?
- What would be the implications of alternative ownership scenarios, such as non-profit land trusts, state ownership, or some combination thereof?

This report is a snapshot of what is possible, profitable, and pono. Looking at case-studies from similar climates there are compelling precedents and sound science the world over that support transitioning from conventional to regenerative agriculture. Each specific area will need further research and detail before proceeding.

Japanese sugarcane workers 1885
https://s-media-cache-ak0.pinimg.com/736x/84/42/80/844280dac7ef0154bde250816a634ba2.jpg

Cultivating beneficial relationships between stakeholders is the foundation for the success of any project. We look forward to hearing your stories, addressing your questions and concerns, and incorporating new ideas.

A Brief Overview of Maui’s “Central Valley” and Sugarcane

The central valley of Maui, once a native dryland forest, is now a wind-swept arid landscape with intermittent streams that were once perennial. Streams such as Pulehunui, Kalialinui, Kailua, Pohakukea, Waikapu and others were free flowing until the advent of large scale grazing and logging on upper slopes. This area previously provided nēnē habitat, as evidenced by the name Pu`unēnē; nēnē are now returning to areas such as Waikapu. Most native Hawaiians traditionally lived around flowing water, where the sophisticated ahupua`a-based farming and aquaculture systems were developed. Master farmers and master fishermen grew and raised plenty of food to feed upwards of a million people across the islands.

Before the sugarcane era the central valley was sparsely populated and was not intensively farmed. The birth of the sugarcane industry changed the face of the central valley and all of Maui forever. Water from the northeast coast of Maui was diverted to irrigate the sugar crop, impoverishing stream ecosystems and negatively impacting communities by restricting their access to water, and hence their ability to grow traditional foods. The once-parched land flourished with this abundant water, and the sugarcane industry has dominated the local economy for almost one hundred and fifty years. Waves of immigrant workers came to seek their fortunes, worked the cane fields, and settled down to raise families.

The sugarcane industry the world over has shifted to chemical farming and systematic mechanization of jobs. On Maui, as in other places, not only has the number of industry jobs decreased steadily, but the use of more and different agricultural chemicals has contaminated the soil and the main Pai`a aquifer, which is now polluted to the point where the water is considered unsuitable for drinking.

Pesticides, herbicides, fungicides, synthetic fertilizers, and ripening agents such as glyphosate have been applied to the soil for years, with very little independent research available to evaluate any deleterious effects on farm workers, neighbors, the groundwater, the ocean, and endemic wildlife. There are no legal obligations for HC&S to remediate the soils or the aquifers.

This style of agriculture, a monoculture crop with substantial chemical inputs, has been found to be a significant contributor to global warming - rather than sequestering carbon in healthy soil, repeated tillage and the application of nitrogen-based synthetic fertilizers release large amounts of CO2 into the atmosphere. Records show significant amounts of pesticides have been applied to central Maui soils, and these chemicals or their derivatives have now shown up in the soil. Mechanization and global transportation of commodity crops only adds more CO2 to the atmosphere, an externality that industrial agriculture has passed on to the citizens of the world.

Herb Kane's painting of Ka`anapali pre-contact
http://herbkanehawaii.com

Ka`anapali today
www.islandbreath.blogspot.com

HC&S has been unable to compete on the world market in recent years, and after reporting $30 million in losses in 2015, they recently announced they will be shuttering the last remaining plantation, not only on Maui, but in the State of Hawai`i. 675 planters and skilled mill workers will be laid off this year.

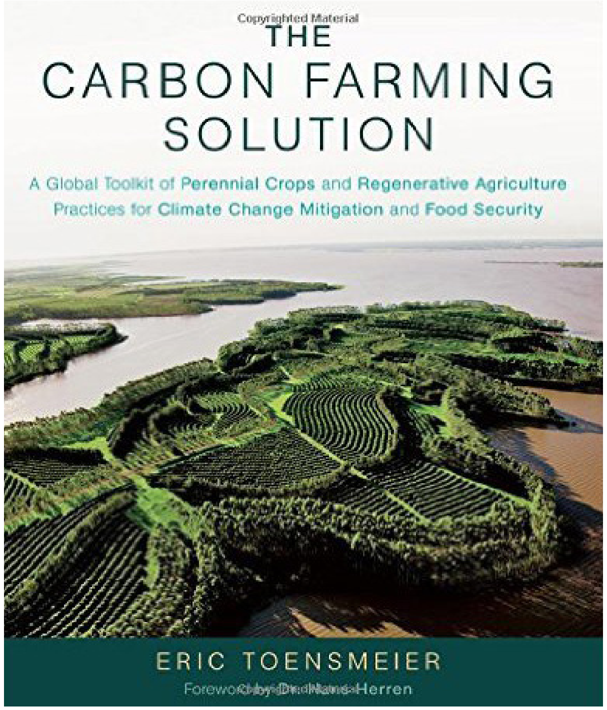
Regenerative Agriculture

Regenerative agriculture integrates specific farm management practices and site design to build ecological and economic resiliency at every opportunity. Regenerative agricultural practices significantly improve upon the USDA National Organic Standards, and are applicable at any scale.

Systematically increasing soil health is the foundation of regenerative agriculture. Building healthy soil improves crop yields and resistance to pests, and makes crops more profitable. It decreases the need for external inputs such as fertilizers and pesticides, improves the water holding capacity by adding organic matter to the soil, and dramatically increases carbon sequestration as a byproduct of the above functions. Regenerative agricultural systems are based on perennial crops with sustained yields using resources generated on-site, as compared to annual agriculture which is often dependent on tillage and external inputs.

Regenerative Agriculture:

- Improves water and mineral cycles on agricultural lands through contour farming and soil conservation methods
- Increases effective precipitation (the percentage of rainfall which becomes available to plants and crops) by improving soil structure and proper grading of land
- Reduces water use by selecting crops that are adapted to the local climate
- Preserves and creates soil through sound soil management practices
- Reduces or eliminates soil degradation and erosion caused by tillage through the use of perennial crops
- Sequesters carbon in the soil through organic production methods, reducing impacts of climate change
- Is based on increasing diversity of both agricultural crops and native species to achieve Integrated Pest Management (organic farming techniques for controlling pest predation)
- Decreases reliance on agricultural chemicals such as fertilizers and biocides
- Integrates livestock that are humanely raised into crop production
- Improves economic resiliency of farming operations through diversified production
- Prioritizes local distribution and value-added products to improve profit margins
- Produces nutrient-dense food products that are healthier
- Improves natural capital and ecosystem services on agricultural lands
- Uses socially just business models like cooperatives, profit sharing, and nested enterprises
- Demands more skilled labor through the diversification of farming enterprises
- Embeds a full complement of necessary agricultural and business skills in the community for generations
- Generates a significant economic multiplier effect in the community, creating real wealth well beyond the agricultural businesses



Cover of The Carbon Farming Solution, by Eric Toensmeier

Regenerative agriculture is based on sound design of the mainframe of farming operations. **This means that the site is designed to reduce or completely eliminate soil erosion from wind and rain through contour farming, proper grading of roads, and covering the soil with plants and/or mulches - the goal is to build soil, not lose it.** Infrastructural elements such as processing centers and agricultural facilities are located near each other to increase efficiency of farming operations, and systems are integrated so that there is synergy and economy of management.

The reduction of water use through the selection of appropriate crops and the increase of effective precipitation through various soil management practices is another very important facet of regenerative agricultural systems. There is a global water shortage, but this shortage is really an issue of management of our water resources as opposed to a lack of water in the environment. Common agricultural practices like tillage, which leaves soil bare, reduces soil organic matter and therefore the capacity of soil to hold and store water. One percent of organic matter added to the soil enables it to hold 8 times more water, allowing the soil to act as a sponge. Shifting to ecologically sound management practices can conservatively increase water-holding capacity of soils by up to 15% or more.

Side by side comparison of conventional grazing (left) and regenerative agriculture (right) grazing lands. http://www.abc.net.au/news/2015-09-16/6780458

Regenerative agriculture is rooted in ancient techniques and wedded to the best of modern agro-ecological technologies. Techniques such as composting and cover cropping for soil building are enhanced with our modern understanding of soil microbiology. Sophisticated rotational grazing of livestock to improve agricultural lands is now more effective with new and evolving practices such as Holistic Management and Management Intensive Grazing.

The business models and corollary social systems - the "invisible structures" - are the foundation for any successful agricultural operation that has the interests of its local community at heart. Regenerative agriculture systematically improves on select business models to build successful and profitable farming enterprises, taking into account the short and long-term health effects on land, water, agricultural workers and surrounding communities.

Maui residents have access to more information than ever before through the worldwide web. The ability to share successes and failures across the globe in real time is perhaps the most important advancement of our culture. This allows the future of Maui agriculture to incorporate improved agricultural systems from other similar climate zones as appropriate to our local culture, thus saving time and investment. A speedy transition to a diversified, sustainable farming model for the lands formerly in sugar cultivation will benefit local workers, enable local food production and and enhance Maui's overall economy.

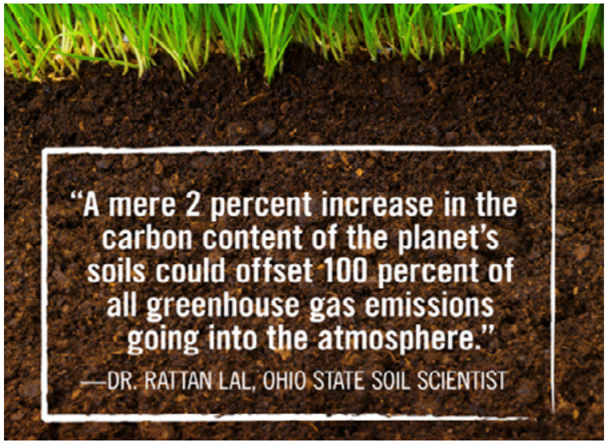
Regenerative Agriculture results:
Loess Plateau, China 1995 (top) & 2005 (bottom)

http://permaculturenews.org/2012/06/28/hope-for-a-new-era-before-after-examples-of-permaculture-earth-restoration-solving-our-problems-from-the-ground-up/

Climate Change and Regenerative Agriculture

Climate change and agriculture are strange bedfellows. Agriculture is responsible for 50% of global greenhouse gas emissions, and is one of the main contributors to climate change. Conversely, climate change negatively affects agriculture. Droughts, floods, and heat waves all have profound impacts on our food production systems leading to crop losses and food supply shortages. Resource scarcity is a leading cause of conflicts globally, as the surge of climate and economic refugees is being linked directly to competition for these resources.

Yet, the problem reveals the solution. As agriculture is a major contributor to climate change, shifting our production methods to regenerative agriculture as described above can also reverse this trend. By some estimates, if all the arable land in the world increased the soil organic matter by 2%, we could reduce atmospheric carbon to pre-industrial levels.



http://ecowatch.com/2015/01/06/regenerative-organic-agriculture/

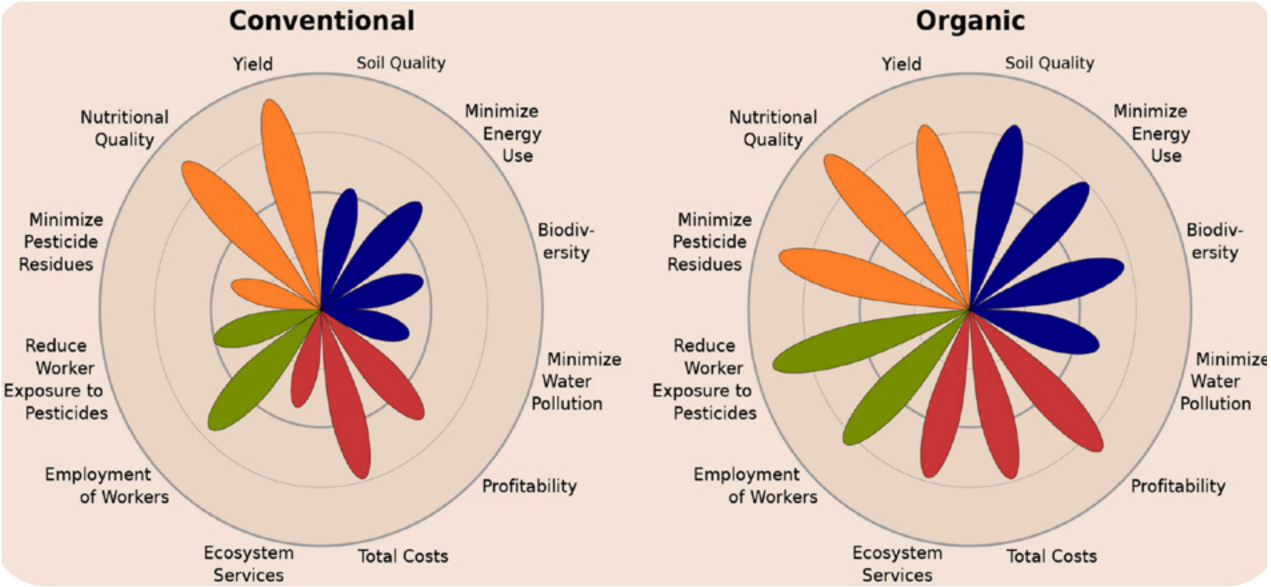
To quote a white paper by The Rodale Institute [1]:

- If management of all current cropland shifted to reflect the regenerative model we could potentially sequester more than 40% of annual carbon emissions
- If all global pasture was managed using a regenerative model, an additional 71% of carbon emissions could be sequestered
- Even if modest assumptions about soil's carbon sequestration potential are made, regenerative agriculture can easily keep annual emissions to within a desirable range

Andre Leu, President of the International Federation of Organic Agricultural movements (IFOAM), provides a thorough review on carbon sequestration in organic soils from diverse sources and ecosystems. These findings are corroborated by international agronomists and climate scientists; quickly converting farms to healthy soils is now a leading topic at climate change solutions forums.

(Endnotes)
1) http://rodaleinstitute.org/assets/

Carbon Farming Educational Series, Permaculture and Holistic Management for Carbon Negative Agriculture



http://beyondpesticides.org/dailynewsblog/2016/02/organic-agriculture-essential-to-a-sustainable-future/

Regenerative Agricultural Land Use Potential and Transition Strategy

From the 15th century on, Native Hawaiian chiefs governed and managed land based upon a system involving mauka-makai land divisions known as ahupua`a. This sophisticated agricultural and ecological management system included complete watersheds from mountain peak (mauka) to reef (makai), with several distinct sub-systems for food production, aquaculture, and communal land use.[1]

The ahupua`a-based management system is a regenerative system; the local environment is continuously improved, and water cycles are maintained, all the while producing abundant foods. Food production and ecosystem functionality go hand in hand, and the system is resilient in the face of drought, flood, fire, and hurricane. Skills, knowledge, and cultural identity grow from generation to generation. Today, upper portions of the watersheds are managed through collaborative watershed partnerships, while most farming land is outside that management system. The Maui Island Plan includes a policy that requires application of ahupua`a-based management to all lands within the watersheds:

All present and future watershed management plans shall incorporate concepts of ahupua`a management based on the interconnectedness of upland and coastal ecosystems/species.

Maui farmers have the opportunity to incorporate the principles of the ahupua`a system into overall land management to meet this goal and reconnect to our agricultural legacy.

Ahupua'a Agricultural Association" of Hawaii (AAA)
Kauai University Web log

Retrofitting the current mono-crop system to one that borrows from the the more crop-diverse ahupua`a-based management system is an excellent way forward. Agricultural land uses would change according to elevation and soil type, exposure, and proximity to infrastructure. Maui has opportunities to implement solutions that require the least change for the greatest effect; this may begin with adding tree crops and livestock to the current sugarcane operation, as outlined below.

Despite the fact that Hawai`i's climate is ideal for the production of many types of crops, there is less than a ten-day supply of food on the islands at any given time.[2] The public is rightfully concerned about our food future, and people are demanding real solutions.

The rationales for transitioning the HC&S operation to regenerative agriculture are many:

- Increase the number of skilled jobs in the agricultural sector
- Satisfy the demand for locally produced food and renewable energy
- Create an economically resilient agricultural operation based on diversified products
- Recharge groundwater and restore hydrological cycles on the land
- Eliminate storm water discharge of agricultural chemicals and come into compliance with the Clean Water Act
- Eliminate air pollution from cane processing and burning, spray drift of agricultural chemicals, and airborne dust
- Address public outcry against industrial farming and GMOs
- Restore water and stream flows to native habitat and farms in East Maui
- Restore native habitats and increase biodiversity on site
- Make it pono by providing access to land for farming through Cooperatives and provide farmworker housing for local workers
- Reduce / eliminate the use of chemical fertilizers and biocides, thus allowing cleansing / remediation of our soils, aquifers, and coastal ecosystems to begin

Regenerative agriculture pays dividends

Regenerative agricultural systems can be more profitable than conventional agriculture, offering better risk-reward scenarios for agri-business and farmers.

According to a recent report by Paul McMahon of SLM partners (an asset manager that acquires and manages rural land on behalf of institutional investors) there are a number of reasons why these types of systems can deliver superior risk-adjusted returns:[4]

- **Comparable or better yields in most cases**
- **Lower operating costs because of less reliance on external inputs**
- **Enhanced natural capital, with the opportunity to increase asset values by regenerating degraded land**
- **Climatic resilience because healthy soils cope better with droughts and floods**
- **Positive environmental externalities and the chance to be paid for them, for example through carbon credits**
- **The ability to sell to higher value markets such as those for organic or grass-fed meats**
- **Higher profitability with less volatility**

Converting 32,400 acres of industrial sugarcane to diversified organic regenerative agriculture will take many years and the final outcome will likely be very different than what we now imagine most practical. We must chart our course, and be prepared to adjust as the winds and tides dictate.

Designing the 'visible structures' - the plants and animals, windbreaks and terracing - is the easy part. Designing new 'invisible structures' – the contracts and agreements, business models, fair and inclusive governance, and land access – is much more challenging; however, if done properly, the result can be transparency, inclusivity, and shared prosperity.

This transition will require an adaptive management strategy. The system must be able to respond to cultural patterns, biological indicators, and economic pressures - it must be resilient. Nature is our model, as resilient systems have evolved over eons. By mimicking natural systems we create agricultural and cultural systems that are dynamic and respond to change and external pressures without wholesale collapse.

10 year regenerative agriculture transition to tree crops using sugarcane for fodder, swales on contour for water infiltration, and aquaculture

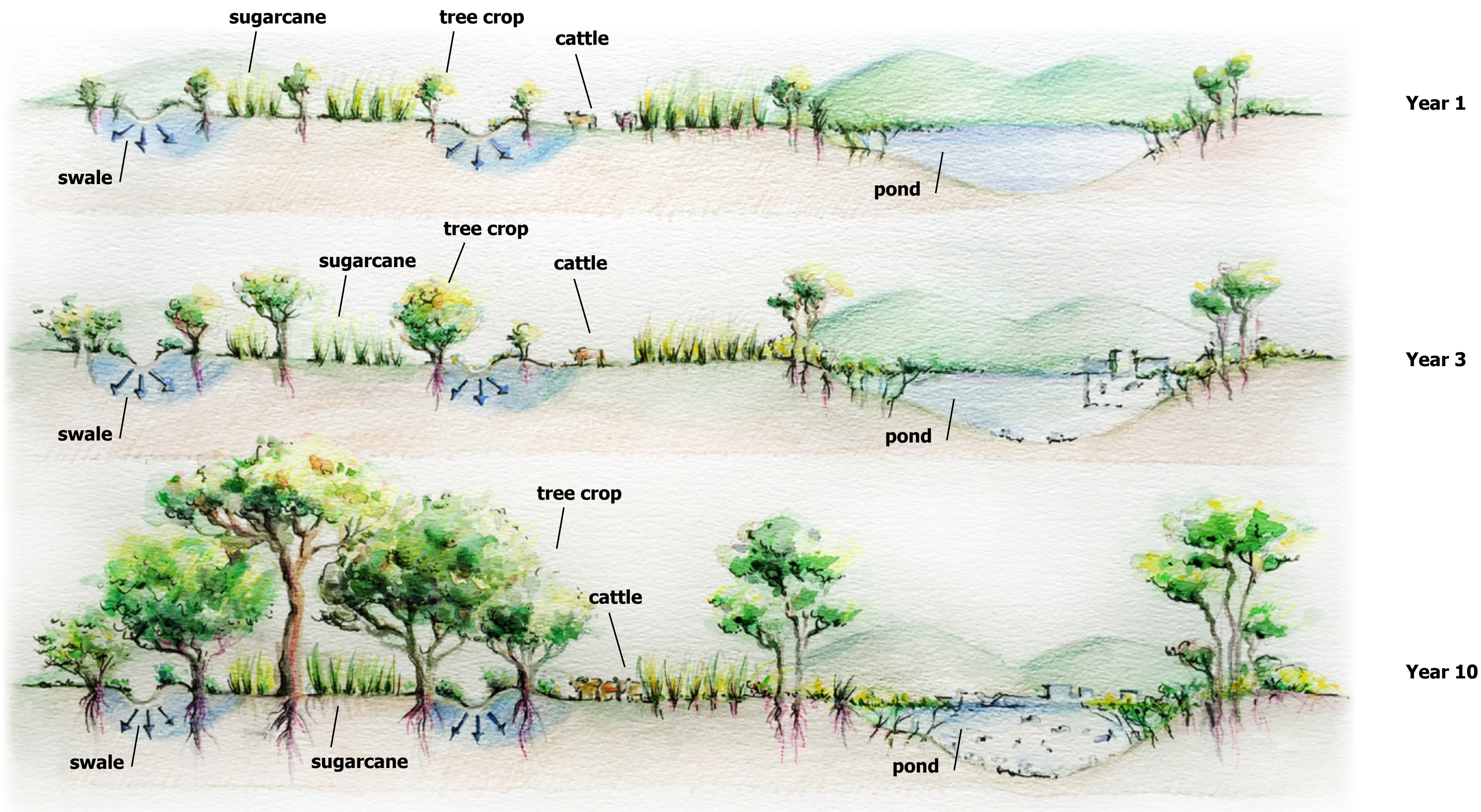
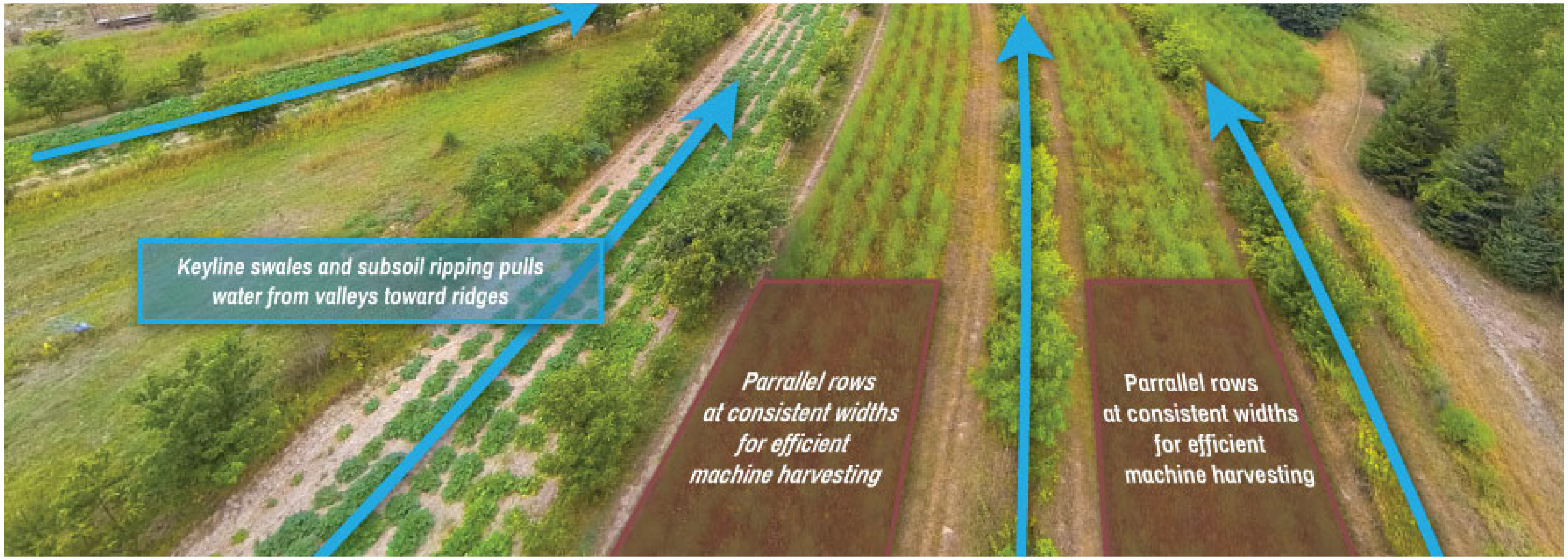


Illustration by Silvia Yordanova



Keyline Design, photo by Mark Shepard, New Forest Farm

Retrofitting Sugarcane Operations and the Transition to Regenerative Agriculture

The most sensible way forward to transition the HC&S plantation to regenerative agriculture is to retrofit the current sugarcane operation. A fresh look at the intrinsic characteristics and benefits of sugarcane will help us understand how management practices could be shifted slightly to take advantage of existing infrastructure and resources currently available.

While beyond the scope of this report, a detailed Business Plan could be prepared to examine what percentage of current HC&S field and processing employees would be needed in the early years of a regenerative agriculture program to harvest and process higher value-added cane products. Further, this Business Plan could review whether HC&S's current mill on Maui could be retrofitted, and at what cost, to process these new products.

The Business Plan would analyze whether the sale of additional sugar related products could generate enough funding over some time period to cover additional employees and infrastructure costs related to future regenerative agriculture operations.

Sugarcane, or kō, is a traditional Polynesian canoe crop that has been transplanted the world over because of its very desirable characteristics and adaptation to varied soils and regions.

Sugarcane is *the* champion crop with respect to carbon sequestration and soil building.[5] It is one of the best tropical fodder crops for livestock, including cattle and swine. In its raw state, sugarcane juice is actually very nutritious. Raw cane juice is high in polyphenols, vitamins and minerals such as calcium, potassium, magnesium, manganese, and iron, along with a complete profile of essential amino-acids. It has even been found to lower cholesterol--both LDL and triglycerides, and is high in antioxidants.[6]

Sugarcane's outstanding characteristics are:

- Its perennial growth habit
- The quantity and nutritional quality of sugarcane increase with harvest interval, with optimum values being reached at a harvest interval of between 12 and 18 months. This is in marked contrast with almost all other tropical forage crops, which deteriorate in yield and quality as the interval between successive cuts is increased. For this reason sugarcane has been called "ensilaje vivo", or living silage in many Central American countries
- The dry matter content of mature sugarcane averages 30 percent, which exceeds that of most other forage grasses (the average for Elephant and King grasses is closer to 17 percent). Thus harvest, transport and processing costs per unit dry matter are less for sugarcane than for most other forages
- There is a long tradition in sugarcane agronomy, especially in breeding, pest control and cultural practices. Admittedly this has been mainly

directed to enhanced production of sucrose rather than total sugars which is the important criterion for animal feed. However, the implication of this practice in terms of the loss of potentially promising varieties is one of degree rather than direction, as there is direct correlation between sucrose yield and feed value.

- Sugarcane is widely tolerant of soil and climatic characteristics and maintaining a canopy of green leaves (or a mulch of dead ones) throughout the year helps to combat erosion, giving it a distinct advantage over competitive forage crops such as cassava and maize[7]

Sugar production on Maui has centered around the crop as a source of sucrose: refined sugar; raw sugar and the value-added products of molasses and rum. There is considerable opportunity for value-added products from sugarcane processing, beyond molasses and rum. There is a market for boutique products from sugarcane, such as organic raw sugar and juice. The antioxidant levels in sugarcane juice are thousands of time higher than the next best vegetable sources, and can sell for as much as $60/kg.[8] There are many uses for the bagasse including alcohol fuels, fiber for disposable plates, and other products. There are many cultivars of sugarcane possessing very different characteristics. Deeper analyses of the conditions unique to Maui can be done to indicate whether ***sugarcane may even be much more valuable converted to soil carbon and animal protein, as opposed to sucrose.*** It could be used as the fuel to feed the transition to regenerative agriculture.

Integrating Trees

The simple act of planting trees has so many beneficial effects. By integrating tree crops into the existing sugarcane fields as contour orchards and windbreaks, the current system may be retrofitted relatively easily and economically.[30]

Trees serve multiple functions:

- Diversifying production
  - Fruits, nuts, and fungi
  - Medicinals and herbs
  - Spices and oils
  - Timber
  - Biofuels
- Providing fodder for livestock
- Decreasing overall water usage and improving water cycling
- Windbreaks for protection
- Moderate temperatures
- Sequester carbon while producing oxygen
- Biomass for soil remediation
- Increasing the overall diversity of the system

Contour Orchards

Contour orchards may be established by planting tree rows directly into the sugarcane fields on contour at 120 foot centers, creating alley cropping and silvopasture systems. Trees can be planted mechanically at the rate of several thousand per day per planting team. Additional herbaceous cover crops can be undersown to sugarcane fields to manage and prevent weeds, and improve the physical, chemical, and biological characteristics of the soil.

Integration of trees will reduce the total acreage of sugarcane significantly. If the total acreage devoted to sugarcane was reduced by 30-50% by replacing with tree crops with less water demand, then the cumulative water use would conceivably be reduced by that fraction. In addition, contour farming and rainwater harvesting earthworks combined with organic soil building strategies will offset supplemental irrigation even more.

Multi-Function Windbreaks

Winds have many harmful effects upon soil, plants, and animals, that are exacerbated as wind speeds increase. These impacts include drying of the soil and resultant loss of nutrients and biota, and increased plant and livestock stress resulting in reduced production and performance.

To minimize and even eliminate the impacts of wind stress, windbreaks of diverse tree, shrub, and deep-rooted herbaceous species are sited across the landscape. Generally windbreaks are oriented perpendicular to the wind's dominant direction; however, while there is commonly a dominant wind direction, winds can and do occur from any direction at any time of the year. A 'net pattern' of windbreaks both down and across slope will significantly buffer winds in the central valley while supporting bio-remediation and providing important ecosystem services. In certain areas the windbreaks may be oriented on contour as part of Agroforestry, Holistic Range Management, and other production systems.

Windbreaks are a significant feature of the mainframe design for the central valley's regenerative agricultural system, providing many key services while increasing the aesthetic value of the landscape.

Multi-Function Windbreak
https://www.agric.wa.gov.au/land-use/establishing-effective-windbreaks-swan-coastal-plain

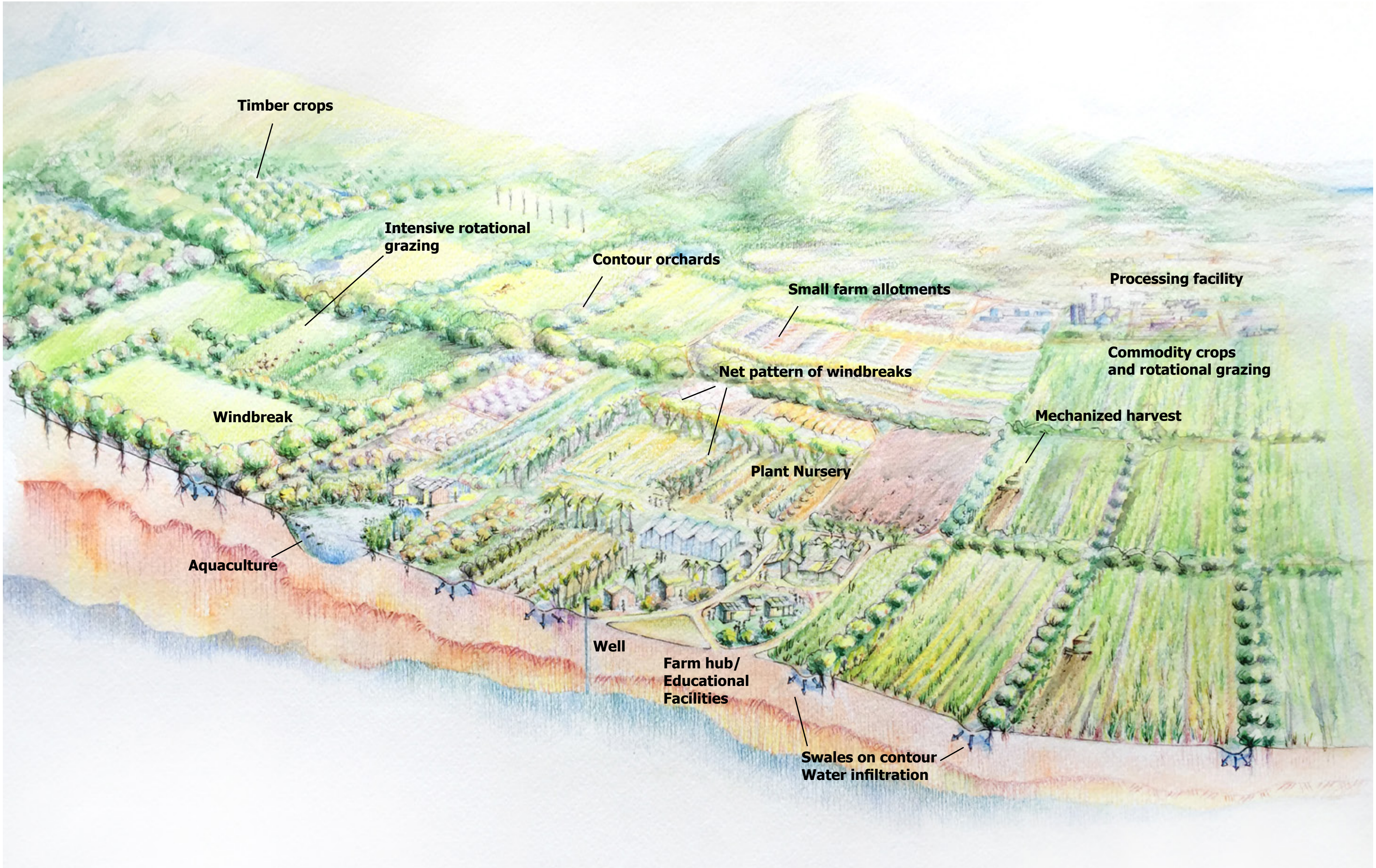


Illustration by Silvia Yordanova

Mainframe Design

The future of any successful regenerative agriculture venture hinges on excellent **Mainframe Design and Implementation**, as well as good management. The following design features must be prioritized as part of the transition strategy, as the success of the whole system is predicated on proper implementation of these elements.

In the case of the HC&S plantation, many existing elements may be retrofitted only slightly to maximize efficiency and economy. Below is a sequence of what that process may look like. Since the site is relatively dry, particular emphasis must be placed on harvesting the rain.

Conceptualized Implementation Sequence of Retrofitting Mainframe Design Elements:

1. Integrating tree crops into sugarcane alley cropping systems on contour while maintaining equal distance as much as possible to facilitate harvesting
2. As much as possible, shifting to contour farming for sugarcane fields for soil preservation
3. Planting multi-function windbreaks
4. Adjusting the shape and orientation of fields and grading the site to maximize rainwater harvesting, increase groundwater recharge, build soil, and eliminate erosion and storm-water runoff
5. Improving access, roads, ponds, and ditch systems to assist the above functions
6. Planting forestry blocks on slopes too steep to farm on contour
7. Implementing diverse soil remediation strategies
8. Restoring habitat to field borders, roads, ditches, and drainage gullies by planting native trees and shrubs
9. Researching and developing value-added products for local distribution and export
10. Creating cooperative business models to allow access to land for local farmers
11. Locating and building Farm Hubs; clustering facilities for processing, fertility management (composting and fertilizer production areas), plant nurseries, and agricultural sales facilities in order to increase efficiency of operations
12. Locating farm dwelling villages and affordable housing for farmers and farm labor
13. Integrating alternative energy production into operations, like solar and wind power, hydroelectric, biodiesel, and methane/biogas

Managed timber interplanted with commodity crops
http://www.aftaweb.org/latest-newsletter/tempo-rate-agroforester/94-2006-vol-14/april-no-2/86-summa-ry-of-the-silvoarable-agroforestry-for-europe-safe-proj-ect.html

As the Mainframe elements are designed, planted, and built, a thorough study of appropriate crops should be conducted. These include:

- Annual crops - vegetables and row crops
- Herbaceous perennial crops - perennial vegetables and fodder crops
- Tree crops - fruits, nuts, timber, and fodder crops
- Cereals and grain crops - including pasture cropping [9]
- Livestock systems - ruminants, swine, fowl, invertebrates, and aquaculture
- Biofuels - both annual and perennial
- Textiles - including fiber and dye crops
- Specialty crops - including spices, medicinal herbs, cut flowers, cosmetic and essential oil crops

The selection criteria for crops may include:
- Low supplemental water needs
- Suitability to soils and climate
- Nutritive value
- Marketability and consumer demand
- Potential for job creation and value adding

Certain systems will work better together and should be appropriately linked. ***Isolating any one of these cropping systems is like taking one note out of a song - there is no harmony.***

Methods to Reduce Overhead

In addition to the production of crops, designing for energy independence of farming operations is important. There are many types of energy that farms rely on, from petrochemical to biological. Fuels and nutrients run the farm.

Production of Compost

The value of adding biologically active compost to the soil is measured in the reduction of operational expenses for materials such as fertilizers and biocides, as well as electricity and fuels costs for pumping irrigation water. As a plant relies on the macro-nutrients to produce sturdy roots, stems, and fruits, it also relies on macro and micro-nutrients to build up immunity to pathogens.

The production of compost is important as a source of humus and for the recycling of agricultural wastes. Compost is actually the final stage of the energy cascade of agricultural products. Below is a conceptual sequence of the "energy cascade" of an agricultural product in regenerative agriculture (in this case fruit), from source to sink;

Agricultural Product Energy Cascade:

- Agricultural product: fruit
- Process: pulp for juice product
- Mash from juicing (adding value to processing "waste" feeds livestock such as for swine and layer chickens)
- Manure and feed scraps are used in a variety of composting operations
    - Anaerobic composting/methanogenesis generates biogas to run boilers or produce electricity
    - Thermophyllic compost can generate hot water
    - Vermicompost (worm compost)
- End uses for compost
    - Apply to fields
    - compost tea injection
    - soil medium for nursery plants

Biogas: Methane Production
George Chan of ZERI (Zero Emissions Research and Initiative) developed sophisticated systems for maximizing returns and reducing overhead for agricultural operations by integrating anaerobic methane digesters to process agricultural wastes. The production of biogas for power produces sludge that can be used to produce algae for animal feed and feedstock for vermi-compost.[10, 11]

Vermicompost
Vermicompost is an excellent solution to the accumulation of organic wastes on farms. It produces high-quality compost using worms with the added benefit of reproducing the worms

Pigs grazing in the understory
http://silvopasture.ning.com/photo/pigs-at-hop-kins-woods-low-res?context=user

Holistic management vs. desertification in South Africa
http://sheldonfrith.com/2015/11/23/the-future-of-agricul-ture-is-regenerative/

themselves, a high protein animal feed for chickens, fish, and pigs. The value and potential for worm composting on Maui is reported but certainly understated.[12] Extensive research has been done in Mexico using worms to compost "cachaza", a by-product of sugarcane processing[13]; this would be a natural choice for diverse fertility and soil-building strategies on Maui.

Pruning as a Management Practice
Pruning and coppicing are important management practices to increase soil organic matter and manage shade in agroforestry systems. Plants are specifically cultivated for biomass to provide feedstock for livestock and mulch. There is further opportunity to integrate biomass energy (syngas) from coppice wood.

Fodder trees can be mechanically pruned and the forage dropped in the field, and livestock allowed to graze on the wilted foliage leaving manure residue to enrich the soil. Better yet, the animals can browse shrubs for late season stockpiled fodder.

Integrated Pest Management
The species diversity of regenerative agricultural systems provides a built-in Integrated Pest Management (IPM) function, further reducing reliance on agricultural chemicals. Insects and birds reduce pest populations, and maybe take a little fruit or nectar for their services. Yield is not only measured in production volume, but reduced expenses of operations.

Mechanization
Because of the scale of this operation, some degree of mechanization will be necessary as a transitional strategy and long-term reality. Therefore the layout of the plantings should reflect this, and have appropriate access for harvesting and pruning equipment.

Livestock and Holistic Management
Maui's cattle industry dates back to 1793. The Maui Cattle Company, six independent family-owned businesses with over 60,000 acres of prime grazing land, states as their mission "the re-invigoration of an agricultural lifestyle through the establishment of a sustainable ranching industry".

The demand for local beef far exceeds the island's production capacity. Most meats are currently exported off-island, and even if all the meat raised here were consumed locally it would only supply 20 – 25% of the Maui market.

Livestock production doesn't just feed people, it creates a wealth of skilled jobs in and around the industry - diversified production of multiple species, research, industry support, processing, value-added products, distribution and marketing, pasture consulting, business management, and more. Prioritizing meats for local markets requires a local abbatoir or slaughterhouse. Expanding and improving the livestock industry into Maui's central valley will require further research and analysis.

Holistic Management

Holistic Management is a systems approach to decision making that includes land planning, grazing planning, financial planning, and biological monitoring as they all relate to one another in the context of an agricultural operation. Holistic Planned Grazing is one aspect of the Holistic Management process, and is a revolutionary livestock management practice that mimics natural herbivore behavior with domesticated livestock. This method has been proven to be one of the best and most expedient ways to repair damaged ecosystems and reverse desertification.

Holistic Planned Grazing uses cattle and other ruminants that are moved frequently so their impact does not harm the land but rather benefits it. Much like a herd of wild herbivores responding to predator pressure, herds are constantly on the move, only grazing the tops of plants. Pasture is allowed to rest so that overgrazing does not occur, and plants are allowed to recover and release carbohydrates into the soil, feeding soil microbes.

Sunflowers and lavender
http://imgc.allpostersimages.com/images/P-473-488-90/26/2659/D8DUD00Z/posters/steve-vidler-sunflower-fields-provence-france.jpg

Harvesting sunflowers
https://i.ytimg.com/vi/YpzTinI65iM/maxresdefault.jpg

With proper management, weedy species are replaced by more beneficial pasture species, and soil organic matter builds rapidly.

Livestock are bunched together in small groups called mobs, and their grazing patterns shift in response to increased competition for pasture; basically they eat weeds and other plants they

may pass up if they were in a set stocked system with little competition for feed. Stocking rates can be doubled or tripled, with up to one million pounds of livestock per acre possible, in rapid rotation. Livestock may be moved daily and even hourly, depending on the forage quality and quantity, and paddocks may be rested for up to one year depending on conditions and management to allow recovery.

Multiple species can be integrated into one management system for diversified production. For example, cattle can be followed by pigs, which can be followed by chickens. The cattle browse grasses and forbs, pigs root for insects and tubers, and chickens eat fly larvae in the manure of the previous species, reducing the vectors for disease. These animals all work in synergy and complement each other, much like the wild populations of animals that are diverse and occupy various niches. This is an example of stacking systems in time. Economic opportunities and a cascade of skilled jobs are the result of diversifying operations.

Ancillary Agricultural Enterprises

There is considerable opportunity for embedding ancillary agricultural enterprises within the Holistic Management system early in the transition, such as:

- Breeding and sales of organic open-pollinated heirloom seeds
- Nursery plants - including native, edible, and ornamental plants
- Organic fertilizer production - including compost and microbial inoculants
- Value added products - including preserves and fermented foods
- Construction products - including timber and bamboo
- Agri-tourism - including farm tours, fresh farm lunches and dinners, direct sales of value-added farm products, and educational workshops
- Regenerative agriculture training and implementation programs

Plant Breeding and Seed Production

Seed saving, genetic selection, and animal breeding techniques have traditionally been passed down through intact farming lineages. Over time “landrace” cultivars and breeds develop that are hardy, resilient, and perfectly adapted to local conditions.

Modern plant breeding has been relegated to seed companies and research institutions. Hybrids and genetically modified organisms are usually patented and their genetic material owned by the companies who produce them. It is technically illegal to save these seeds, or propagate them without paying royalties. Farmers now need to buy their seed every year, and sadly saving seed has become an antiquated, and sometimes illegal practice.

Silvopasture grazing with sheep
https://www.flickr.com/photos/baalands/2216308884/

Cattle grazing on leucaena, a perennial nitrogen-fixing fodder crop
http://portfolios.pratt.edu/gallery/3880677/Rethinking-food-production-in-the-tropics-research

Plants reproduced through biotech engineering, hybridization, or clonal propagation are genetically identical. Mono-crop plantings of clones are more susceptible to pests and diseases, as pathogens need only crack the code of one genetic makeup to infect the whole field. In nature all plants are sexually propagated through pollination, therefore their genetic makeup is varied. This means pests and pathogens must crack the code of many genetic expressions, conferring natural disease resistance to native populations. [31]

There is an enormous need globally for open-pollinated seed varietals of both annual and perennial crops. While many sources for open-pollinated and heirloom annual vegetable seeds exist, there are very few seed companies that develop fruit and nut tree seed with stabilized traits – qualities that come true to type when planted. Changes in climate are creating the need for new provenances that are adapted to increasingly variable climatic conditions.

Hawai`i can grow certain seed crops that yield three harvests each year. Large GMO seed corporations have successfully and profitably capitalized on the unique attributes of Hawai`i’s favorable climate, year-round sun, and available water. HC&S lands have locations suited to lease to organic open-pollinated seed companies, if they were recruited to relocate here to Maui. This nationally expanding agriculture sector provides good, highly skilled jobs. Local workers could be trained in these breeding and harvesting protocols.

Developing a breeding program for fruit and nut trees, much like was done by the legendary plant breeder Luther Burbank - who developed the russet potato and other improved fruit tree varietals - is much needed in the world, especially Hawai`i. The islands are well suited to testing new and improved seed varieties, as evidenced by the many biotech companies who have seed trials here.

Hawai`i needs to develop new landrace seeds that have desirable characteristics, are adapted to the local climate, that are true to type, and make this seed available to farmers and gardeners to propagate at will. This is the real foundation of food sovereignty and security.

The University of Hawai`i College of Tropical Agriculture and Human Resources (CTAHR) recently began work on The Hawai'i Public Seed Initiative, which emphasizes the importance and value of local seed systems. Working with the Kohala Center, they have gathered baseline data, taught seed-saving workshops, created seed networks on all the islands, and are establishing statewide and regional variety testing trials. [32]

Educational Opportunities
One important limiting factor inhibiting the proliferation of regenerative agriculture in Hawai'i is the lack of trained farmers. This is certainly not exclusive to Hawai`i; it is a global issue. Again, the problem reveals the solution. The sugarcane fields can be used as a living classroom to train farmers, and the initial curriculum would parallel the transition phase plan.

Regenerative agriculture practices build deep rich soil (left), compared side-by-side with conventional grazing soil (right) at Winona Farm in Australia.

The potential for creating a world-class educational curriculum on this site should not be understated. The demand for this type of learning experience is as great as the demand for the food these systems produce. There is a serious lack of hands-on trainings for aspiring farmers, farmers wanting to move out of conventional farming, as well as seasoned farmers. An ongoing educational series can be developed in partnership with the many existing Maui institutions that will attract professionals from around the world.

As a venue, Hawai`i and Maui are in high demand, and this project expands on the ever-growing sector of agricultural and educational tourism. Recruiting the world's leading regenerative designers as instructors and hands-on trainers can put Maui on the map for excellence in regenerative agricultural education.

Examples of workshops and regenerative agriculture trainings include:
- Stakeholder process and community engagement
- Whole Farm Design
- Regenerative Agriculture Design and Management
- Holistic Management and Livestock Operations
- Tropical Agroforestry Design and Management
- Seed Breeding and Plant Propagation
- Earthworks Design and Implementation

There is significant income potential for educational offerings. Students regularly pay $200/day for specialized trainings from 4 days – 2 weeks, and attend longer in-depth courses for certification-level trainings.

http://www.glenwoodgarden.com/wp-content/uploads/2014/06/SAGE-Food-farms-future-image-logo.jpg

Case Studies and Precedents
There are a growing number of successful regenerative farms sprouting up in Hawai`i and across the world. It is important to look to existing success stories to glean information applicable to central Maui lands. The challenges that these enterprises have faced over their development provide the most valuable information we can seek in order to avoid similar mistakes and move forward swiftly. The following case studies were chosen as they are particularly relevant to Maui, showcasing projects from similar climates, farm businesses that integrate sugarcane, profitable livestock operations that regenerate farmlands, and demonstrate how farmers have diversified income from multiple products within a mainframe design.

Organic Sugarcane Production
Sugarcane Best Cultivation Practices, Brazil
Brazil has done pioneering work in developing and studying no-till management of sugarcane production, particularly for ethanol production. In a 15 year study, they found that no-till sugarcane operations provide many benefits to both the farms, the soils, and the environment. Through the combination of no-burn and mechanical harvesting while leaving the dry matter on the

field, no-till sugarcane operations eliminate the air pollution caused by burning and at the same time create a net increase in soil carbon stocks of 9.7 Mg/hectare. Rather than coming at the expense of yields, no-till sugarcane operations yield 10 tons more per hectare than conventional plantings. Fertility is cycled by returning the sugarcane byproducts from the processing mills to the field and growing nitrogen-fixing cover crops such as sunn hemp (Crotalaria juncea) as a green manure. Advantages to no-till management of sugarcane include reduced costs in soil preparation, increased organic matter in the soil, improved fertility, reduced fertilizer applications, reduced compaction, reduced erosion, and lower emissions of greenhouse gases.[14, 15]

No-till Systems
The Brazilian sugarcane industry employs modern agronomic management practices to enhance productivity and protect the environment. Key features of Brazil's sustainable approach to cultivation and processing include:

Low Soil Erosion
Brazilian sugarcane fields have relatively low levels of soil loss, due in part to the semi-perennial nature of sugarcane. The same plant will grow back many times after it is cut, and its cane juice is extracted. In fact, sugarcane is typically only replanted every six or seven years. The Brazilian industry also emphasizes farming techniques that preserve soil stability while yielding approximately 34 tons of sugarcane per acre, as compared to an average of 11.5 tons per acre at HC&S.[30]

Strategies include:

- No-till production systems
- Crop rotation with soybeans or peanuts
- Green fertilization by planting cover crops such as Crotalaria juncea or using leftover sugarcane straw after mechanized harvesting as ground cover

Silvopasture at Pongamia, Australia

Thanks to these responsible agricultural practices, soil erosion in sugarcane fields is minimal when compared to many other crops such as rice and soybeans (For more information, read the "Environmental sustainability of sugarcane ethanol in Brazil" study). In some regions of the country, sugarcane has been produced on the same soil for more than 200 years with continuous yield and soil carbon increases.[16]

Organic Sugarcane Production, Ingenio El Mante, México
Nacho Simon recognized that the "cachaza", a by-product of sugarcane processing, was a problem for the majority of operations, so he decided to transform it into compost and return it to the fields. The addition of micro-organisms to the soil was very beneficial, as his soils had been depleted from repeated harvests.

The organic matter is the food and home of the life in the soil, and maintains the equilibrium and also transforms the dry waste in the fields to nutrients. The organic matter also retains humidity, reduces erosion, and improves the structure and texture of the soil, allowing roots to grow rapidly. The results of applying compost to the fields were a 100% increase in production and also the reduction of operating costs, allowing sugarcane operations to remain profitable.[17]

Cattle: Holistic Management

Florida, USA: Jim Elizondo, RegenGraze
Jaime (Jim) Elizondo of RegenGraze manages Mashona Cattle in an intensive silvopasture system with Leucaena leucophylla in North-central Florida. He also integrates high density grazing on mixed cover crops grown as stockpiled forages, which can be rapidly implemented on conventionally managed farmland under annual cropping and tillage practices.

Understory forages he uses in his intensive silvopasture system include bahiagrass, bermuda grass, torpedograss and a wide variety of herbaceous legumes. He also uses free-choice mineral supplementation based on the work of Mark Bader to improve the overall balance of soil minerals and forage quality for his livestock. Through these integrated systems, Elizondo has achieved cost savings "from $100-200 per cow per year compared to normal practice in the area, plus [he] carries double the normal stocking rate while improving the soil and respecting wildlife."

Starting with low fertility soils, they integrated compost extract liquid fertilizers at one gallon per acre to stimulate the soil microbes for the first two years. Once 100% soil cover was achieved, they stopped applying compost extracts and relied upon crop and litter management to feed soil microbes. Pasture cropping was also practiced, planting into winter perennial pastures with a mixture of summer annuals including lab-lab bean, sunflower, cowpea, hairy indigo, soybean, sudangrass, millet, sunn hemp, and clover.

Cover crops are trampled and harvested as forage using ultra-high density strip grazing (~1,000,000 lb cow/acre moved 4-6x per day during this treatment). Based on his current success, he plans to develop shelterbelts and fodder tree rows of Mimosa and mulberry plantings.[18, 19]

Commodity crops: Textiles and fiber

Winona NSW, Australia: Colin Seis
2,075 acres pasture cropping: cereals, sheep, native grass seed

One of the most powerful innovations in large scale regenerative agriculture is pasture cropping, a system pioneered by Colin Seis at his home and farm Winona in New South Wales, Australia. Colin has been practicing and refining the pasture cropping system on his 840 acre farm since 1992, when a wildfire wiped out his operation. By integrating native warm season perennial pastures with no-till cool season cereal grain production, Colin produces three 'stacked' enterprise product lines from each pasture: sheep wool and meat, cereal grain, and native grass seed. The balance between pasture grazing and cereal cropping is achieved through carefully timed grazing rotations. At the same time, he has decreased annual production costs by $120,000 AUS and increased soil carbon by over 200% in 10 years. While he has decreased costs and improved soil fertility and water holding capacity, his wool quality has also increased. All this is done on 650 mm (26") of avg. rainfall per year. Colin now works to expand his system to other farms and reports "over 2,000 farmers pasture cropping" cereal crops into summer (C4) and winter (C3) perennial native grass in NSW, South Australia, Victoria Queensland, West Australia and Tasmania as well as other areas around the world.[20]

Agroforesty, Contour Orchards, and Alleycropping

Agenda Gøtsch, Brazil: Ernst Gøtsch
Another example of regenerative agriculture transforming a landscape is on a cacao plantation in Northeast Brazil, owned and farmed by Ernst Gøtsch using a form of innovative agroforestry. When Gøtsch purchased the 1,200 acres of unproductive land in 1985, the land, like much in the region, was degraded and dry, considered unsuitable for cacao production.

Once covered in Atlantic rainforest, decades of timber exploitation and cattle grazing had left the land barren and the wells had run dry. Gøtsch used a unique blend of soil recovery techniques that mimic the natural regeneration of forests and reawaken the biology of the soil; within five years water was again flowing in the wells. Within 10 years, he was obtaining 4,500 pounds of cacao per acre--1,250 pounds more than average for his region.

When disease destroyed much of the neighboring cacao plantations, his trees were untouched. He was generating 2-3 cm annually of new topsoil. The Atlantic Rainforest resurfaced on his 1200 acres, bringing with it its flora and fauna. Nearly 900 acres of his farm are now a natural heritage reserve. After 20 years, 14 springs have reappeared on the farm.[21]

Diversified Operations

Finca Luna Nueva, Costa Rica
This research project is unique in that it combines all three types of land use management on the same tropical farm - reforestation, cattle/pasture management, and commercial crop production. Crops that are grown include: cassava, turmeric, ginger, taro root, sweet potato, banana, plantain, corn, various beans, various leafy greens, and vegetable crops. Cattle are dual-purpose, bred for

Laguna Blanca Farm, Argentina, diversified agriculture with terracing on contour
http://www.tompkinsconservation.org/farm_laguna_blanca.htm

meat and dairy production. The reforested land was once in open cattle grazing, and now has been replanted to native humid tropical rainforest.[23]

Laguna Blanca, Argentina:
Tompkins Conservation
7,418 acres; acquired in 2007
Project of Kris and Doug Tompkins, Dolores Peréa-Muñóz and Eduardo Chorén, Entre Ríos Province, Argentina

Laguna Blanca is in the midst of a dramatic transformation from industrial monoculture to organic polyculture. Comprising more than 7,000 acres at the confluence of the Feliciano and Parana rivers in northeastern Argentina's Entre Ríos Province, Laguna Blanca offers an opportunity to develop a model of diversified organic agriculture for the region.

When it was purchased in 2007, Laguna Blanca was in serious need of restoration: its infrastructure needed attention, and its soils were eroding away. To counter erosion, terraces were built to create level fields in which a variety of grains—including oats, flax, sorghum, barley, and wheat—are now grown. New orchards produce eleven fruit and nut species, including peaches, pears, olives, dates, hazelnuts, pecans, and almonds. Many aromatic and herbal species are being cultivated alongside a wide assortment of horticulture crops, many of which are perennial varieties requiring zero tilling. Sheep graze in restored native pastures, and hay is made to feed them through the winter from the grasses surrounding the orchards. The practicality of this polyculture style of farming is becoming increasingly evident as interactions between diverse crops, healthy soils, and native wildlife are improving the farm's yields.[22]

Aquaculture/Aquaponics

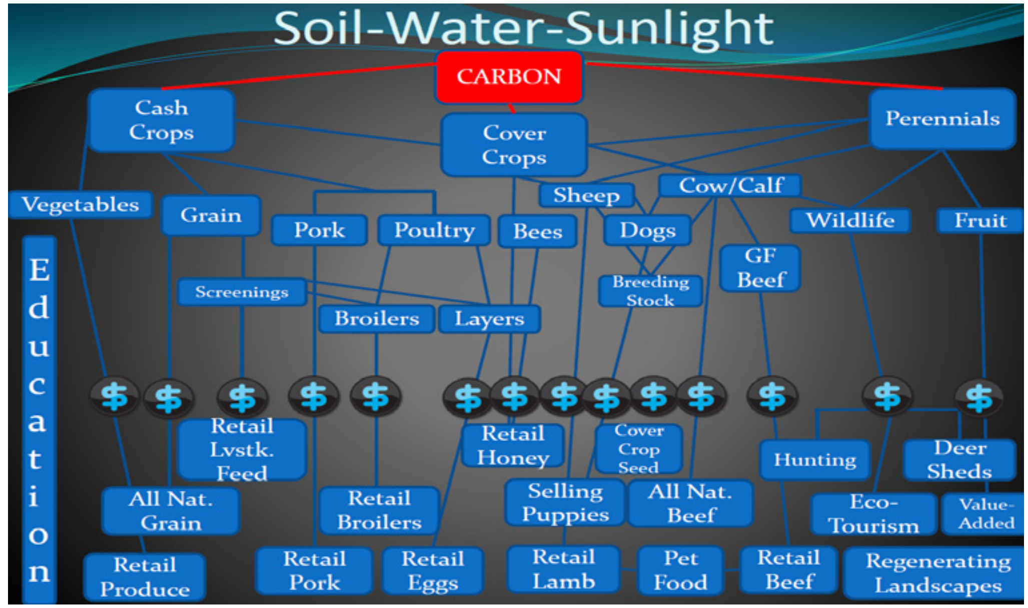
Hawai`i, USA

There are several examples of successful commercial aquaponics enterprises in Hawai`i, including Kunia Country Farms[24] on Oahu, and Living Aquaponics[25] on Hawai`i Island. Both of these enterprises are on the order of one-quarter acre of total land area. Living Aquaponics is generating between $1,500-$3,000 gross income per week ($75,000-150,000/yr) with three people working 20 hrs/wk. They have been in business for five years and have managed to work through the challenges of disease and pest management in organic aquaponics with leafy greens and root crop production even during Hawai`i's warm and wet seasons.

Biofuels

Pongamia silvopasture, Australia

Pongamia pinnata is an exciting legume tree native to Australia which tolerates a variety of climate conditions including salty soil, and can be integrated into silvopasture systems for biofuels production. Trees in trial plots of ~300 acres are producing 16kg of seeds per tree and 'elite' cultivars have produced up to 100kg of seeds per tree annually. In addition to producing biodiesel, the seed cake left after oil extraction can be fed to livestock as a supplement to silvopasture forage and fodder, allowing fertility to be returned to the system.[26]



Gabe Brown's Nested Enterprise model

Enterprise Systems

Gabe Brown's Nested Enterprise Model[27,28]

Although from a different climate, this case study showcases a number of successful diversified farming income streams on one farm using sophisticated regenerative agriculture techniques. The cascade of products shown in his Nested Enterprise chart are directly applicable to Maui.

Gabe Brown is rapidly building soil on more than 5,400 acres by merging back-to-basics agrarian practices with innovative, science-based sustainable farming techniques on his diversified family ranch in North Dakota. Beyond converting all cropland to no-till, he constantly seeds with a cocktail of dozens of cover crops. Through Holistic Management, a diverse cropping strategy, rotational grazing and no-till practices the farm has benefited in terms of soil health, mineral and water cycles, greatly reduced inputs, excellent production and profit, and an improvement in quality of life for the farmers.

Gabe Brown has been practicing his form of integrated regenerative agriculture for over 15 years. For decades the cropland had been conventionally farmed with tillage and the use of synthetic fertilizers and herbicides. Tillage had lowered organic matter levels to less than two percent. In 1993 Brown purchased a no-till drill and converted 100 percent of his cropland to no-till. Brown employs a diverse cropping strategy on his grain and cattle operation which includes over 25 different cash and cover crops, resulting in high yields and strong net profits. The Natural Resources Defense Council awarded one of its 2012 Growing Green Awards to Brown and says, "Gabe's trailblazing work has made him a leader in regenerative ranch management."

Educational Agritourism
Rancho San Ricardo, México

Using the magic of Keyline® and ingenuity, the Mashumus team has converted a mono-cropped sugarcane plantation in Mexico to one of the best examples of permaculture and organic agriculture in the world. With over 140 acres of sugarcane, the project was conceived by Pablo Ruiz Lavalle and Eugenio Gras of Mashumus to be one of the most innovative agricultural education sites of our time. Roads, ditches, fruit orchards, and the entire infrastructure were redesigned to harvest water, capture carbon, improve fertility, and beautify the landscape at the same time. Here, local cane growers who manage the surrounding 32,000 acres are able to learn the techniques of Keyline®, the secrets of biofertilizers and microorganisms, natural building techniques, and a myriad of other eco-technologies.[29]

> *Keyline planning is based on the natural topography of the land. It uses the form and shape of the land to determine the layout and position of farm dams, irrigation areas, roads, fences, farm buildings and tree lines. Keyline is an agricultural system in which great emphasis is placed on processes designed to increase substantially the fertility of soils. Emphasis is placed on the creation of a soil environment that rapidly accelerates soil biological activity, thus vastly increasing the total organic matter content within the soil. Keyline lay-outs of farm and grazing lands also incorporate designs permitting the storage of run-off water on the farm itself.*

The central valley of Maui is a large enough area to influence the local climate. Powerful winds bring energy and nutrients that can be harvested or deflected, including moisture, micro-organisms, minerals, and pollutants. Trees can help to mitigate the effects of the wind on this vast tract of land, and benefit the operation and local environment in many ways.

Regenerating our agriculture offers solutions to many of the “problems” facing the world today- water and food shortages, soil loss, rising energy prices and climate change. It may seem that agriculture has nothing to do with these issues, but in fact it has everything to do with them, and can address them all as a win for everyone.

(Endnotes)

1)http://www.hawaiihistory.org/index.cfm?fuseaction=ig.page&CategoryID=299
2)http://hawaiitribune-herald.com/sections/news/local-news/bills-promote-food-self-sufficiency.html
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26)http://www.bioenergyplantations.com.au/update-on-roma-trial-plantation-progress/
27)https://greencoverseed.com/sites/default/files/attachments/Gabe%20Brown-Livestock%20Integration.pdf
28)http://www.acresusa.com/gabe-brown-large-scale-rapid-building-of-soil-with-cover-crops
29)http://mashumus.com/index.php/proyectos
30) while yielding approximately 34 tons of sugarcane per acre, as compared to an average of 11.5 tons per acre at HC&S (http://hcsugar.com/wp-content/uploads/2013/02/hcs_factsheet_2013_130201PDF.pdf) .

Water and Soil

Wai: water, Waiwai: true wealth.

Malama `āina: to care for and nurture the land so it can give back all we need to sustain life for ourselves and our future generations

The Constitution of Hawai`i states:
For the benefit of present and future generations, the State and its political subdivisions shall conserve and protect Hawai`i's natural beauty and all natural resources, including land, water, air, minerals and energy sources, and shall promote the development and utilization of these resources in a manner consistent with their conservation and in furtherance of the self-sufficiency of the State.

All public natural resources are held in trust by the State for the benefit of the people.

The State shall conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally suitable lands.

Water

The majority of Hawai`i has a tropical climate and receives copious rainfall. However Maui's central valley is in a rain shadow and receives between 15 and 60 inches of rain annually, so the 36,000 acres currently being farmed by HC&S is technically in a drylands/sub-humid micro-climate. Sugarcane, one of the world's most thirsty crops, could not be grown here without abundant supplemental irrigation.

This irrigation water arrives at the property in a series of long canals that divert streamflow from more than 100 streams in West Maui and East Maui, and four main streams on the North East coast of Maui. Between 160-390 million gallons per day are diverted from these sources. As a result, these streams no longer can support the native habitat they once did, and the communities that live within their watersheds no longer have access to this water for farming and other uses.

East Maui Irrigation ditch
Photo by Will Scullin

Every day on Maui over 400 MGD of water, fresh and brackish, is used for domestic, industrial, commercial or agricultural purposes. Only around one-eighth, or 45 MGD of that amount is used for domestic and commercial use. Less than one-tenth of Maui's water resources are actually under public control, although billions of gallons of water originate on public lands. **The vast majority of present use is for agricultural irrigation.**[1]

Control of the water is serious business on Maui. It is incumbent upon the next generation of farmers in the central valley to strive for smart water use and employ best practices that systematically reduce demands for agricultural irrigation, and

Illustration by Silvia Yordanova

Swales are long, level excavations which are constructed on contour across the landscape to slow the flow of water, store water in subsoils, and create fertile and diverse planting microclimates. They are not intended to encourage or allow water to flow but to simply hold the water by promoting infiltration into the soil. Swales will vary greatly in width and length depending on the dictates of the land and design parameters.

The soil is excavated on the contour and normally mounded on the downhill side on the swale. The swale system creates prolonged subsoil moisture, and provides excellent drainage for trees.

that also bank water in the soil across the region. Restoring East Maui watersheds must be a priority in any central valley farm design. Regenerative agriculture addresses this issue convincingly.

Strategies of Regenerative Agriculture to Improve Hydrological Cycling:[2]

- Capturing and storing rainwater through
  - Terracing
  - Building swales on contour
  - Keyline plowing
  - Ponds
- Building healthy soil to improve water holding capacity through using
  - compost
  - mulch
  - cover crops
- Planting windbreaks to decrease evapotranspiration and harvest atmospheric moisture
- Using rotational grazing to improve soils
- Planting climate adapted crops that require minimal irrigation
- Using conservation tillage methods
- Using efficient irrigation methods
- Planting perennial crops requiring no tillage

In a 30-year farm systems trial, the Rodale Institute found that corn grown in organic fields had 30 percent greater yields than conventional fields in years of drought. Healthy soil that is rich in organic matter and microbial life serves as a sponge that delivers moisture to plants. **The trial also found that organic fields can recharge groundwater supplies up to 20 percent.[3]**

A study released by Cornell University Professor David Pimentel in 2005 reported that organic farming produces the same corn and soybean yields as conventional farming and uses 30 percent less energy and less water. Moreover, because organic farming systems do not use pesticides, they also yield healthier produce and do not contribute to groundwater pollution.[4]

Coffee under nitrogen fixing leucaena overstory: http://afrique-orientale-australe.cirad.fr/en/research-in-partnership/ongoing-projects/ecological-intensification/safse

Organic citrus orchard with herbaceous understory http://www.goldengroveorchard.com.au

Water Demand of Various Commodity Crops

Water demand varies greatly depending on climate, soils, cultivation practices, and species or cultivar selection. A brief look at alternative crops and livestock management shows significant potential reductions in total water use for the HC&S property.

The data below is derived from conventional systems and does not represent efficiencies possible in regenerative agricultural systems. Very little data is available for regenerative systems but it is assumed that water use would be as much as 10-30% less than the numbers below when you account for all other factors.

Sugarcane: HC&S current water use averages approx. 200 million gallons per day (mgd) on 36,000 acres

- Low end: ~ 5,500 gallons/acre/day
- High end : ~ 8,000 gallons/acre/day
- Includes irrigation and other uses
- *Assume 5,000 gallons/acre/day is accurate for irrigation, if 500 gallons/acre/day for other uses

Carob: 0.5-1 acre feet/acre/year

- Low end: ~500 gallons/acre/day
- High end: ~900 gallons/acre/day

Avocado and citrus average: 2-4 acre feet/acre/year
- Low end: ~1,700 gallons/acre/day
- High end: ~3,500 gallons/acre/day

Macadamia = 3-4 acre feet/acre/year
- Low end: ~2,700 gallons/acre/day
- High end: ~ 3,500 gallons/acre/day

Mango: 5-9 acre feet/acre/year
- Low end: ~4,400 gallons/acre/day
- High end: ~8,000 gallons/acre/day

Sunflower:
- Could be rain fed = no irrigation = 0 gallons/acre/day

Dryland Kalo:
- Planted at the beginning of the rainy season, dryland kalo is rain fed in areas with 6-9 months of rain (the time required for the crop to mature). Supplemental drip irrigation would be required in the central valley

Cattle:

- One cow can drink up to 25 gallons/day
- If stocking rates are 2 head per acre, that is 50 gallons/acre/day for drinking
- Pasture is normally rainfed and requires no supplemental irrigation
- No hay will need to be fed in lean times if trees and shrubs are used as supplement to grass
- The only water needs of holistically managed livestock systems are for the stock themselves
- Compaction of soils through conventional farming activities and the removal of trees and organic matter reduces effective precipitation. Soils that are bare and hard will not absorb rainfall, leading to erosion and ultimately desertification.

Regenerative agriculture offers many solutions to this crisis, addressing the issue at every level, mauka to makai, from rainfall to aquifers. The thorough integration of elements in the Mainframe design of the system ensures that less water will be used in the production of crops, and more water will be stored and available, banked in ponds, soils, and plants. Streams and springs may return, and local rainfall may increase through orographic effects if the central valley is designed with the intention to improve the hydrological cycles of the land.

Soil

Bioremediation of Soils

Healthy soil is a dynamic living ecosystem, teeming with billions of microorganisms that continuously create humus, nourish plant growth, hold water, and sequester stunning amounts of carbon. Soils that are exhausted and contaminated from years of conventional agriculture tilling and chemicals have very little microbial action, but can be restored over time using specific targeted strategies depending on the level and types of pollution. The legal requirement to make the transition from conventional to certified organic agriculture is three years. The obvious first step is to stop using chemicals altogether, and then begins the journey to robust and healthy soil.

Soil is a complicated substrate, and mechanisms for the metabolism of chemical pollutants are not completely understood. The research shows that healthy populations of microorganisms in the soil have the capability of bioremediating certain pollutants.[6] Even metals can be bound in the soil by humic acids.[7]

Definitions:

Bioremediation: The use of soil microbes to remove or neutralize contaminants in polluted soil or water. Bacteria and fungi generally work by breaking down contaminants such as petroleum into less harmful substances. Plants can be used to aerate polluted soil and stimulate microbial action. They can also absorb contaminants such as salts and metals into their tissues, which are then harvested and disposed of.

Biodegradation
Petroleum hydrocarbons will degrade with relative ease as a result of biological metabolism. Although virtually all petroleum hydrocarbons are biodegradable, biodegradability is highly variable and dependent somewhat on the type of hydrocarbon.[8]

Phytoremediation is the direct use of living green plants for in situ removal, degradation, or containment of contaminants in soils and groundwater. Advantages of phytoremediation include that it is generally low cost and has low energy requirements; has a low environmental impact; and contributes to landscape improvement. It provides habitat for animal life, reduces surface runoff and reduces the dispersal of dust and contaminants by wind. It is suitable for large areas of land.[9]

Rhizofiltration is a form of phytoremediation that involves filtering water through a mass of roots to remove toxic substances or excess nutrients.

Mycoremediation
Of particular interest are fungi and mycorrhizae, which have the ability to tie up inorganic salts in waxy excretions, and degrade pollutants (many agricultural chemicals are inorganic salts). Mycorrhizae are destroyed by tillage, emphasizing the importance of no-till systems. Stimulating microbial and enzyme activity, mycelium reduces toxins in situ. Some fungi are hyperaccumulators, capable of absorbing and concentrating heavy metals in the mushroom fruit bodies.[10]

To understand the extent and type of chemicals present, extensive soil testing is required across a site to measure baseline levels of pollutants. Consistent monitoring is important to document the efficacy of treatments. The most appropriate remediation protocols will depend on the type and quantity of chemicals present.

Soil Building Strategies and Bioremediation

Korean Natural Farming

Korean Natural Farming (KNF) involves the collection and cultivation of indigenous microorganisms (bacteria, fungi, nematodes, and protozoa), and then reintroducing these microorganisms directly into agricultural systems to build rich and fertile soil. Using on-farm resources and recycling farm wastes, KNF minimizes dependency upon costly external inputs[11] and consistently produces higher yields without the use of chemical fertilizers.

The strategies and techniques of KNF were developed by Master Han Kyo Cho at the Janonge Natural Farming Institute in South Korea.[12] KNF has demonstrated its success to such a degree that it was adopted by the South Korean government. Rice farmers have since experienced larger yields, saved money on inputs, and are able to sell their rice for a premium. It has had the added benefit of cleaning the waterways, rivers, and even coastal waters.[13]

Farmer Samson Delos Reyes walks along kalo patches at S& J farms of Walanae; Photo by Jamm Aquino http://www.activistpost.com/wp-content/uploads/2011/01/natural-farm.jpg

Master Cho teaching on the Big Island of Hawaii http://natural-farming.weebly.com/about-mr-cho.html

Since its introduction into Hawaii in 1999 by Dr. Hoon Park, KNF has been gaining in popularity with local farmers. Numerous trainings and workshops have been conducted on the islands. The University of Hawaii's College of Tropical Agriculture and Human Resources (CTAHR) has published many articles on the techniques, established a Natural Farming Agent position and conducted field trials that have demonstrated improved plant health, increased yields and improved soil tilth using KNF techniques. [14]

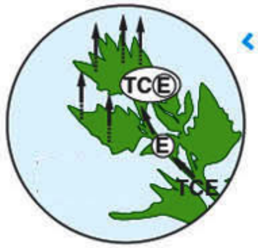
Farmers in Hawaii are reporting success with KNF. Samson Delos Reyes of S&J Farms of Waianae stated in an article in the Honolulu Star Advertiser that since trying Korean Natural Farming, production on his 10-acre plot has doubled. "This is the first time having earthworms on my farm," he said, scooping up a handful of earth and nutrient-rich worm castings in his fingers. "They're cultivating the soil for me." His land was once classified as 'unsuitable for farming.[15]

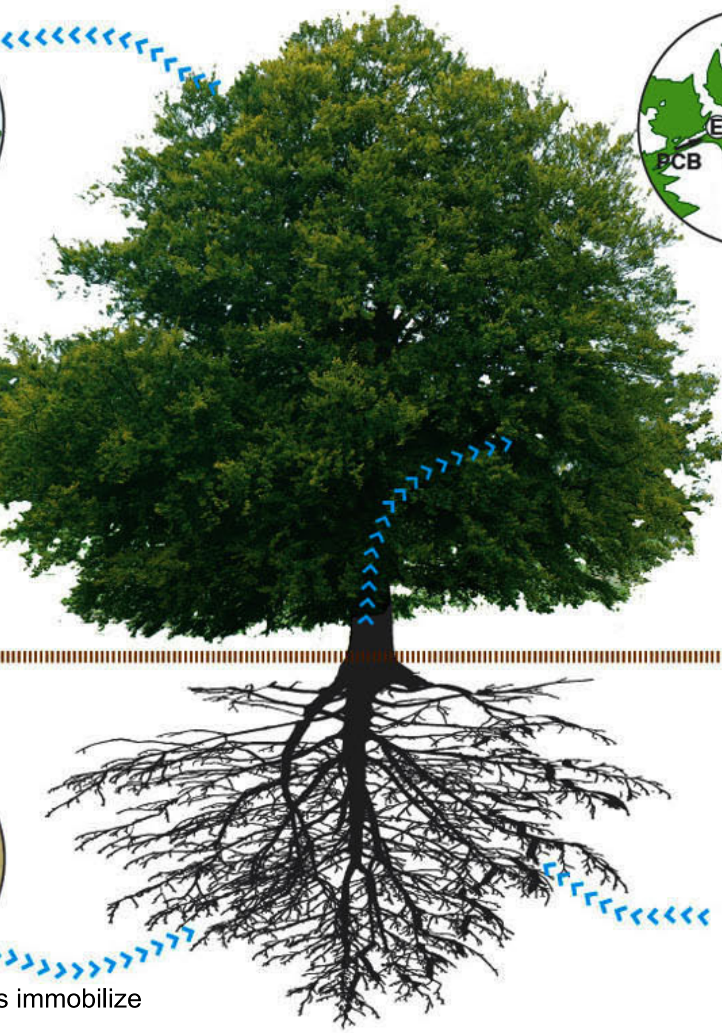
Chris Trump and his family have been farming 750 acres of macadamia nuts in North Kohala for 25 years. They began experimenting with Korean Natural Farming 5 years ago. Currently, they have 120 acres in its second year of utilizing KNF techniques. By August of 2016, they intend to utilize KNF on all 750 acres. He states, "This works. It is also organically certifiable and safe."

While field trials in Hawaii have thus far been conducted on a small scale, large scale experiments have been conducted in other parts of the world. Mr. Cho conducted an experiment in the Gobi Desert where previous tree planting efforts had failed three times due to harsh winds and very limited rainfall of the area. The trees he has planted using KNF techniques have had a 97% survival rate and are currently 20 feet tall. Corn and grasses have been

PHYTO VOLATILIZATION:
Some plants take up volatile contaminants and release them into the atmosphere through transpiration. The contaminant is transformed or degraded within the plant to create a less toxic substance before and then released into the air.

Contaminants are modified along the way and evaporate



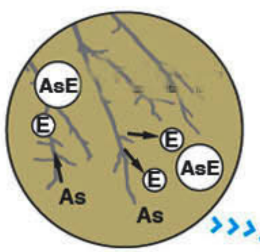


Enzymes fragment contaminants and produces new plant fiber

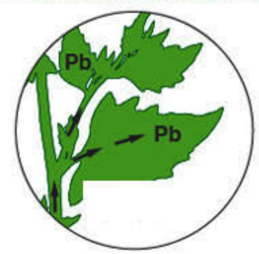
PHYTO DEGRADATION:
Plants take up and break down contaminants through the release of enzymes and metabolic processes such as photosynthetic oxidation/reduction. In this process organic pollutants are degraded and incorporated into the plant or broken down in the soil.

PHYTO EXTRACTION:
Plants take up contaminants - mostly metals, metaloids and radionucleids- with their roots and accumulate them in large quantities within their stems and leaves. These plants have to be harvested and disposed as special waste.

PHYTO STABILIZATION:
Some plants can sequester or immobilize contaminants by absorbing them into their roots and releasing a chemical that converts the contaminant to a less toxic state. This mechanism limits the migration of contaminants through water erosion, leaching, wind, and soil dispersion.



Enzymes in the roots immobilize contaminants



Contaminants taken up into plant tissue

Soil remediation
urbanomnibus.net/2010/11/from-brownfields

planted as well for livestock feed, and wells have been dug. Watermelon farming now provides a stable income to farmers.

Master Cho expressed a keen interest in working with Maui County to teach and implement KNF in the central valley at his workshop in January, 2016.

Cover Crops

Cover cropping is the strategy of seeding a mixture of plants in a fallow field or within a perennial or annual cropping mix for the purposes of increasing soil fertility and organic matter content. It improves soil structure, controls erosion, holds water in the soil, manages weeds and diseases, and increases biodiversity. Cover cropping is also proven to increase carbon sequestration in the soil. The basic process of cover cropping is to sow a field after harvest with a variety of plant species which are then lightly tilled into the soil when they first start to show flower buds.

Soil fertility is enriched by the variety of plant species in the cover crop mix, which usually includes nitrogen fixing species such as legumes, and dynamic accumulators, which concentrate macro and micronutrients in their leaves. Examples of dynamic accumulators include sunflower, rye, buckwheat, sesbania, and mustard. Soil organics and structure are improved via the plant's rooting and with the tilling in of all plant material.

Cover crops further protect and bind the soil structure from compaction and erosion by rain and wind. The management of water is greatly improved as the vegetative cover vastly reduces any run-off, while significantly increasing infiltration rates due to its roots and improved soil structure, i.e. high percentage of soil air gaps. Covered soil dramatically reduces water loss by reducing exposure to the drying effects of the sun and wind.

Crimson clover cover crop fixes nitrogen, suppresses weeds, prevents erosion, and provides excellent forage for honey bees.
http://media.oregonlive.com/washingtoncounty_impact/photo/clover-001jpg-a027abb64673b3af.jpg

These effects increase and protect soil biology, and promote a living and dynamic soil ecology. Cover cropping reduces the presence of weeds by reducing their ability to germinate, occupying space that they would usually need, and by making it difficult for the weeds to complete their full life-cycle, thus not being able to produce seed. Certain cover crop species, rye and mustard as examples, have been shown to have allelopathic effects that suppress weeds and disrupt disease cycles.

Water and soil are the foundation for agriculture, and for society as a whole. Nations rise and fall following the health of their soils. It is our imperative to leave a legacy of clean abundant water and healthy organic soils for our children, our keiki. We must malama ` āina.

Luckily, we have options for improving and restoring these vital resources that sustain life, for us and for all the earth's inhabitants.

(Endnotes)
1)Lucienne de Naie and Marty McMahon, M.A., Ka Waiola Project 2002-2004
2)http://www.cuesa.org/article/10-ways-farmers-are-saving-water
3)http://www.rodalesorganiclife.com/home/organic-methods-hold-water
4)https://www.organicconsumers.org/news/reports-show-less-water-used-organic-farming
5)http://hcsugar.com/keeping-maui-green/water-conservation/
6)http://dge.stanford.edu/SCOPE/SCOPE_38/SCOPE_38_3.2_Matsumura_79-90.pdf
7)http://www.ext.colostate.edu/mg/gardennotes/212.html
8)U.S. Environmental Protection Agency, 2009
9)http://www.hawaii.edu/abrp/biotech.html#anchor155092
10)http://www.hawaii.edu/abrp/Technologies/fungus.html
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12)Reddy, Rohini (2011). Cho's Global Natural Farming. Retrieved from https://ilcasia.files.wordpress.com/2012/02/chos-global-natural-farming-sarra.pdf
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Multi-level Diversified Business Opportunities

Challenges facing local food production include access to affordable land for farmers, competition from foreign markets, a lack of skilled farmers, insufficient local processing and distribution facilities, and the lack of marketing and business skills of farmers. As a result of the above factors, food industry customers are unable to secure consistent supply of quality local produce.

There are, however, significant opportunities for local food production in Hawai`i, specifically on Maui. There is considerable demand for high quality local produce, with many people willing and able to pay a premium price for locally grown organic products. Maui schools, retailers, hotels and restaurants are all seeking local produce, with only a limited supply available. Exact numbers are outside of the scope of this report, but suffice to say that there is opportunity for multi-million dollar yearly contracts to supply local, island-wide, and export markets.

Maui County has extensive resources already in place to facilitate local agricultural enterprise and value-added innovation (manufacturing processes that increase the value of raw agricultural products). These include a large offering of classes, commercial kitchen facilities, small business mentoring, and a robust consortium of partners working to build capacity for agriculture enterprises.

Maui Food Innovation Center
The Maui Food Innovation Center (MFIC) provides business and technological expertise to food and agricultural entrepreneurs throughout the State of Hawaiʻi. A program of University of Hawaiʻi Maui College, MFIC helps farmers and food manufacturers increase profitability through the development of new value-added food products, reduces our dependence on imports, and contributes to the sustainability of island-based agriculture.

Maui Food INNOVATION CENTER

Workshop with interns at HaleAkua Garden Farm

MFIC has secured funding through the Hawaiʻi State Legislature to renovate the former campus cafeteria in the Pilina Building at UH Maui College in Kahului into a state-of-the-art, shared-use food processing facility. This facility will have the capacity to design, test, and produce foods such as sauces, soups, jams, jellies, entrees, bakery products, dehydrated snacks, refrigerated fresh-cut produce, and raw or cooked meat, poultry and seafood products.

Sustainable Living Institute of Maui
The Sustainable Living Institute of Maui (SLIM) is a center with a primary focus on non-credit based community outreach and development activities, as well as complementing UH-Maui College credit-based activities. These activities include the development and dissemination of knowledge and the provision of services to the County of Maui community in various areas of sustainability, particularly renewable energy and sustainable agriculture.

College of Tropical Agriculture and Human Resources
CTAHR is a land-grant university that provides exceptional education, research, and extension programs in tropical agriculture and food systems, family and consumer science, and natural resource management for Hawaiʻi and the international community. Topics of recent articles and workshops included moringa, pineapple, beekeeping, soils, legal issues for growers, breadfruit, and aquaculture. Through its CTAHR Extension, the College provides numerous publications, trainings, support staff, and project assistance for farmers.

The Kohala Center [1] on Hawai`i Island has generated numerous excellent and in-depth reports on agriculture, aquaculture, biofuels, livestock, and other important farming and watershed issues.

There are many professional, non-profit, and government agencies/institutions working together to help create a vital farming future for Maui.

Skilled Farmers

It is a fact that Maui does not currently have the skilled farmers nor the business infrastructure to support a full-fledged transition to scores of diversified agriculture enterprises. On 32,400 acres there is ample room for large commodity crop and livestock operations exceeding 5,000 acres (biofuels, timber, and cereals), operations from 1,000 – 5,000 acres (hemp, kenaf, fruit and nut orchards,), and numerous businesses that can span the 5 – 500 acre range (vegetable, nurseries, seed crops, aquaculture).

Maui County, A&B, HC&S, and non-profit organizations will have to invest in several strategies to jump-start farming businesses. These include providing incentives and assistance to local farmers, recruiting successful farmers from off-island to start businesses on Maui, recruiting and training new farmers, providing mentorship, and financial assistance.

Farm Incubators

Farm incubators provide land-leasing arrangements for beginning farmers who have farming experience and a business idea, but do not have access to land. It is a low-risk environment to launch a farming business and test ideas.


Will Allen from Growing Power teaches aquaponics to students from around the world
http://www.sustainablebrands.com/sites/default/files/imagecache/635x300/article_images/growing-power-fish.jpg

Farmers usually have access to multiple acres of 'shovel-ready' irrigated land, business planning and marketing support, shared equipment and processing facilities, dry storage, greenhouses, and other core infrastructure.

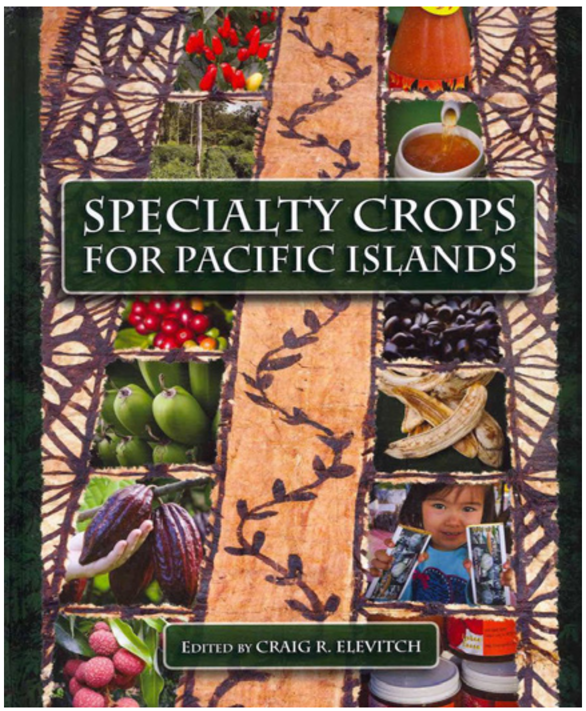
Incubator farms usually have a 3 – 5 year tenure, expecting the farmers to graduate to their own acreage, thereby making room for new business ventures. Often incubators have a number of permanent anchor businesses who provide stability, mentorship, and profitability.

Economic Multipliers and Job Opportunities
The economic multiplier for sugarcane industry jobs is 1.87: for every 1 job directly related to sugarcane production there are 1.87 more jobs created in other sectors.[2] Considering this, the loss of 675 jobs on the sugarcane plantation will result in the loss of around 1,260 jobs total. We anticipate the economic multiplier for regenerative agricultural systems to be higher than this considering value-added processing, diversified production, and increased agritourism.

Still, the bottom line is economics. What kind of profit is possible for diversified agricultural systems? Can local food production be competitive with imports? It has been shown that sugarcane, when grown just for sugar, is not profitable and cannot compete on the global commodities market.

Economic metrics for regenerative agricultural systems are variable, but conservative estimates for diversified agricultural production put net profits at around $5000 to $7500 per acre per year, compared to $50 to $75 per acre per year for sugarcane[3] in a monocrop for export, an increase of almost 100 fold. Some farmers claim to gross, and even net, up to $100,000 to $150,000 per acre per year for direct marketed organic vegetable production. [4]

http://www.oneisland.org/hawaii/



Cover of Specialty Crops for Pacific Islands by Craig Elevitch

Farm Enterprise Opportunities

The sample of farm enterprises listed below is by no means complete, and is meant to demonstrate the potential mosaic of various land uses for the central valley agricultural lands. Each business has its own set of required skills, markets, customers, and distribution. When imagining scores of diverse farm enterprises integrated into a regenerative agricultural mainframe design, it is evident that Maui will create many more than the 675 jobs lost to HC&S closure.

Canoe Crops
Native Hawaiian canoe crops were not traditionally grown in the central valley, but with the reduced water needs of regenerative farming, and some supplemental water, many of these crops will thrive. These crops fed, clothed, housed, and provided medicines in abundance for generations, and are some of the most important crops to consider when analyzing Maui's food systems.

- Kō - Sugar Cane
- `Ohe - Bamboo
- Niu - Coconut Palm
- Kalo - Taro
- Ki - Ti Plant
- Pia - Polynesian Arrowroot
- Uhi - Yam
- Mai`a - Banana
- `Olena - Turmeric
- `Awapuhi - Wild Ginger
- `Awa - Kava
- `Ulu - Breadfruit
- Wauke - Paper Mulberry
- Kukui - Candlenut Tree
- Hau - Hibiscus
- `Ohi`a `Ai - Mountain Apple
- `Uala - Sweet Potato
- Noni - Indian Mulberry
- Ipu - Bottle Gourd

Vegetable Crops and Diversified Fruit and Nut Orchards
Demand for local consumption of vegetables, fruits and nuts far outstrips current production. From direct sales through local farmer's markets up to multi-million dollar annual contracts for Hawai`i's school lunch program, Maui is well-situated to ramp up production. There are cascading job opportunities for value-added products including:

Dried fruits
- Jams and preserves
- Juices
- Fermented products
- Salsas
- Processed nuts and seeds (salted, dipped in chocolate, in trail mixes)
- Superfood blends
- Alcohol distilleries and brewhouses (rum, vodka, beer, wine)
- Essential oils
- Root-crop chips
- Agritourism

Superfood Crops
There is an enormous demand for fresh and prepared nutrient-rich superfoods as exemplified by the spending habits of customers seeking healthier lifestyles. A few examples include:
- Moringa
- Turmeric
- Poha berry
- Acai berry
- Cacao

Aquaculture
HC&S has dozens of reservoirs across the central valley, ranging in size from 1 million gallons to 80 million gallons. Converting several reservoirs to fresh-water fish aquaculture in conjunction

Sorghum is being considered as a biofuel crop for Maui
https://www.bungenorthamerica.com/products/categories/14-sorghum

Growing lettuces with aquaponics at Living Aquaponics Inc.
http://www.livingaquaponics.com

with neighboring farm operation or aquaponics (growing vegetables in conjunction with fish) would further diversify food supplies and provide skilled job opportunities.

Livestock
To raise meats for the local market Maui needs a full-service slaughterhouse, packing house, butcher services, and a mobile slaughter unit. There is demand for fresh meat, cured specialty meats, dairy, and eggs. Please refer to the section on Holistic Planned Grazing for details.

Biofuels
There is a great opportunity to grow biofuel crops to help make Maui more self-sufficient in energy, reduce air pollution, and cut our emissions of greenhouse gases. Biofuels, fuels made from plants and organic matter, are one way to decrease our consumption of fossil fuels, especially oil. Unlike oil, coal, or natural gas, biofuels are renewable and won't run out.[8]

Biofuels include:
- Ethanol
- Biodiesel
- Biogas/methane from anaerobic digestion
- Syngas from biomass gasification

Ethanol made from bagasse, a byproduct of sugarcane processing, has huge potential as a transition fuel for the HC&S property. Brazil is considered as a biofuel industry leader, with the world's first sustainable biofuels economy. Touted as a policy model for other countries, its sugarcane ethanol is called "the most successful alternative fuel to date".[9, 10] Hawai`i had hoped to spur creation of a local ethanol industry, using locally grown feedstocks, with a 2006 requirement

Polyface Farms mobile chicken coops with noticeably improved grass growing just two weeks after grazing rotation.
https://www.pinterest.com/pin/344103846254618977/

that all motor gasoline be blended with 10% ethanol, but no ethanol refineries have been built in the state. In 2015, the requirement was repealed (Act 161, Session Laws of Hawai`i 2015). [17]

Biodiesel crops include sunflower, safflower, hemp, kenaf, soybeans, amongst others. Biodiesel burns cleaner than fossil fuels, and releases fewer pollutants and greenhouse gases into the atmosphere. Pacific Biodiesel, headquartered in Kahului, Maui, has 20 years experience internationally in biodiesel, manages a successful operation of biofuel crops on 10,000 acres on the Big Island of Hawai'i, and is considering expanding to Maui.

"Since its inception over 15 years ago, Pacific Biodiesel has built 12 facilities on the mainland U.S. and Japan, and completed expansions on several of those plants. It's newest venture, Big Island Biodiesel, located on Hawai`i Island, began production in the 4th quarter of 2012. Featuring zero-waste processing, this facility produces the highest quality biodiesel available in the country". [11]

Biodiesel production on Maui could offer lateral job opportunities for former HC&S sugarcane workers. It is a specialized farm business with many jobs in the biodiesel plant itself, and is highly mechanized.

Textiles and Fiber Crops - Kenaf and Hemp

Kenaf (Hibiscus cannabinis) and hemp (Cannabis sativa) are promising commodity crops that merit further research. Both grow well in the tropics, have multiple high-value yields, help with soil remediation, and have potentially large employment opportunities.

Kenaf bales in warehouse
http://www.britsauto.co.za/index.php/natural-fibre-mat/

Harvesting Hemp in Romania:
http://www.hempworld.com/hemp-cyberfarm_com/htms/answers/answr_08.html

Kenaf is a warm season annual fiber crop closely related to cotton and okra that can be successfully grown on Maui. Kenaf has been used as a cordage crop to produce twine, rope, and sackcloth for over six millennia, and today there is a robust market in paper products, building materials, flotation devices, absorbents, high-tech fine oil for industry, biofuels, viable seed, and livestock feed. Kenaf grows quickly to 9' -12', the flowers produce a delicious honey, and can likely produce 2 – 3 crops annually on Maui.[12]

Hemp yields many diverse products from foods to medicine, paper and textiles, building materials and more. Hemp is an excellent soil remediation crop and like kenaf has a long history in twine, cloth, burlap, and other textiles.

Hemp's environmental footprint is relatively small and it requires few pesticides and no herbicides. It's an excellent rotation crop, often used to suppress weeds and loosen soil before the planting of cereals. However, it requires a relatively large amount of water (albeit less than sugarcane), and its need for deep, humus-rich, nutrient-dense soil limits growing locales.[13]

Further research is needed to know if hemp is a viable and profitable crop for Maui, and if it would be invasive, as its seeds are easily dispersed by birds. "Feral cannabis is an exceptionally hardy weed, widely dispersing its seeds which can lie dormant for 7–10 years before sprouting again." [16]

Kenaf and hemp also offer lateral job opportunities for retrained HC&S workers.

Agritourism[14]
As part of a whole-farm strategy that complements the farm enterprise itself, farmers can generate significant income by diversifying into agritourism, especially on Maui. Our 2.6 million annual visitors seek out fun, delicious, and educational day-trips to local farms.

It can be difficult to make a living as a small farmer, and the supplemental income from agritourism, in conjunction with real farming, can be an important part of the solution to profitability. However, this will tend to raise the value, and thus the price, of agricultural land.

There are many ways to drive business to local farms including:

- Farm tours
- Farm-to-table lunches and dinners
- Tastings
- Workshops and trainings
- Ziplines
- Dude ranches
- Fishing/hunting
- Wineries/brewhouses/distilleries
- Gift shops
- Concerts
- Fairs
- Festivals
- Weddings

The Hawai`i AgriTourism Association (HATA) connects the agriculture sector with the visitor industry and residents across Hawai`i. They provide educational and economic opportunities to members that include farm diversification, agritourism marketing, developing farm tours, and producing and selling value-added products.

Tourists enjoying the zipline at Maui Tropical Plantation
http://mauitropicalplantation.com

(Endnotes)
1)http://kohalacenter.org/research
2)http://files.hawaii.gov/dlnr/cwrm/cch/cchma0601/DO-HCS.PDF, page 9
3)https://www.extension.iastate.edu/agdm/wholefarm/html/c3-65.html
4)http://www.nola.com/business/index.ssf/2012/12/high_yields_low_prices_robust.html
5)http://naturalsociety.com/sustainability-on-steroids-organic-farmer-grosses-100k-an-acre/
6)https://radicalpersonalfinance.com/making-80k-on-13-acre-with-an-urban-farm-without-owning-land-yes-please-interview-with-curtis-stone-rpf0040/
7)http://pvs.kcc.hawaii.edu/ike/moolelo/polynesian_plants.html
8)http://www.climatetechwiki.org/technology/agriculture-biofuel-production
9)https://en.wikipedia.org/wiki/Ethanol_fuel_in_Brazil#cite_note-TwoBillion-7
10)Sperling, Daniel and Deborah Gordon (2009), Two billion cars: driving toward sustainability
11)http://www.biodiesel.com
12)http://www.cres.gr/biokenaf/files/fs_inferior01_h_files/BOOKLET.pdf
1)http://modernfarmer.com/2013/10/legal-industrial-hemp-wont-matter/
14)http://www.hiagtourism.org
15)https://en.wikipedia.org/wiki/Ethanol_fuel_in_Hawaii
16)https://en.wikipedia.org/wiki/Feral_cannabis
17)https://en.wikipedia.org/wiki/Ethanol_fuel_in_Hawaii

Community Engagement and Story of Place

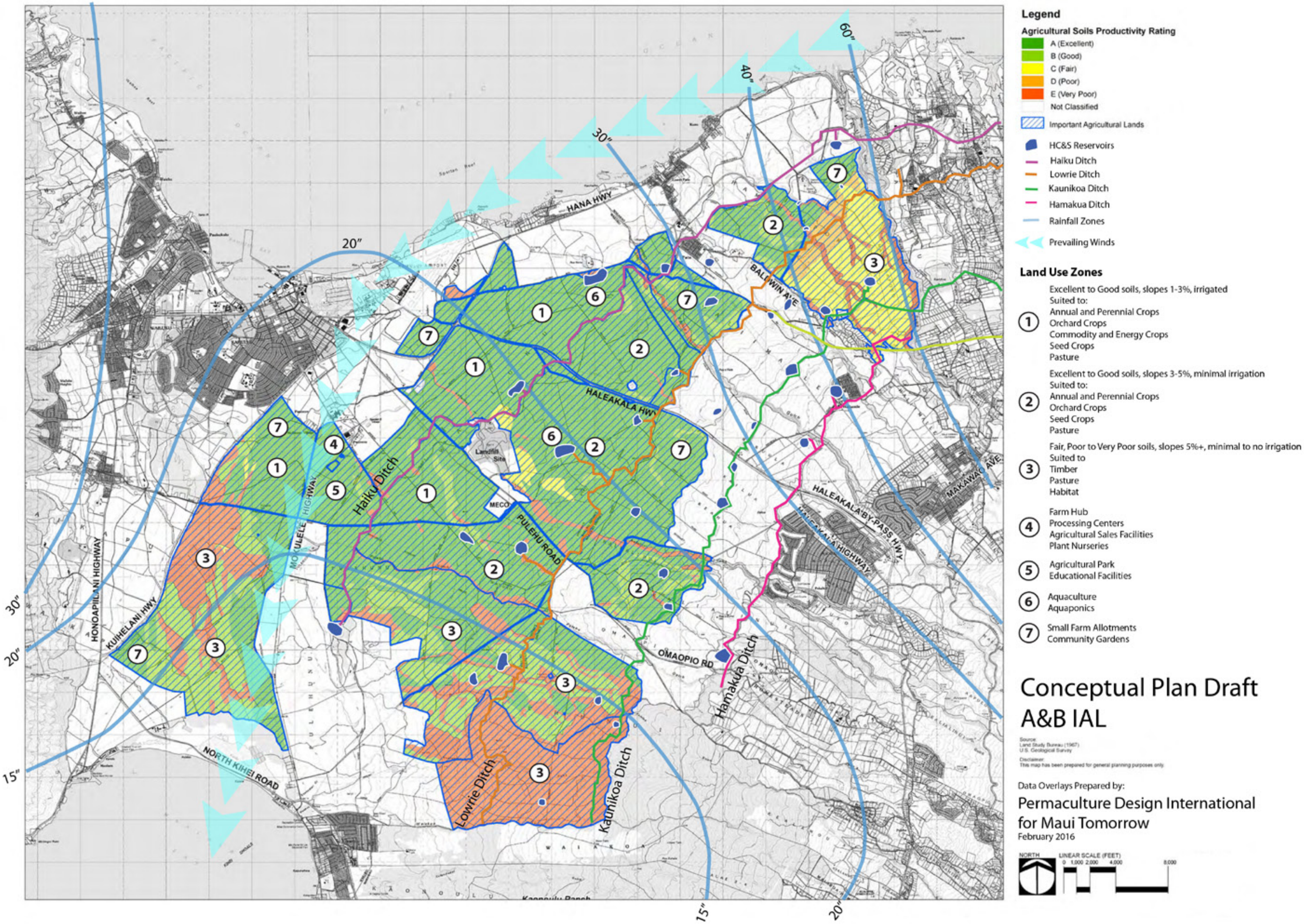
This report has examined many possibilities for how to begin a transition to regenerative agriculture. These options will require a large investment in research, design, implementation, infrastructure, training and much more. The research and potential outcomes outlined in this report are beginnings of a community discussion and vision. The key is to come together as a community, with our largest landowner, and chart this course together.

Moving forward hinges on addressing these important questions:

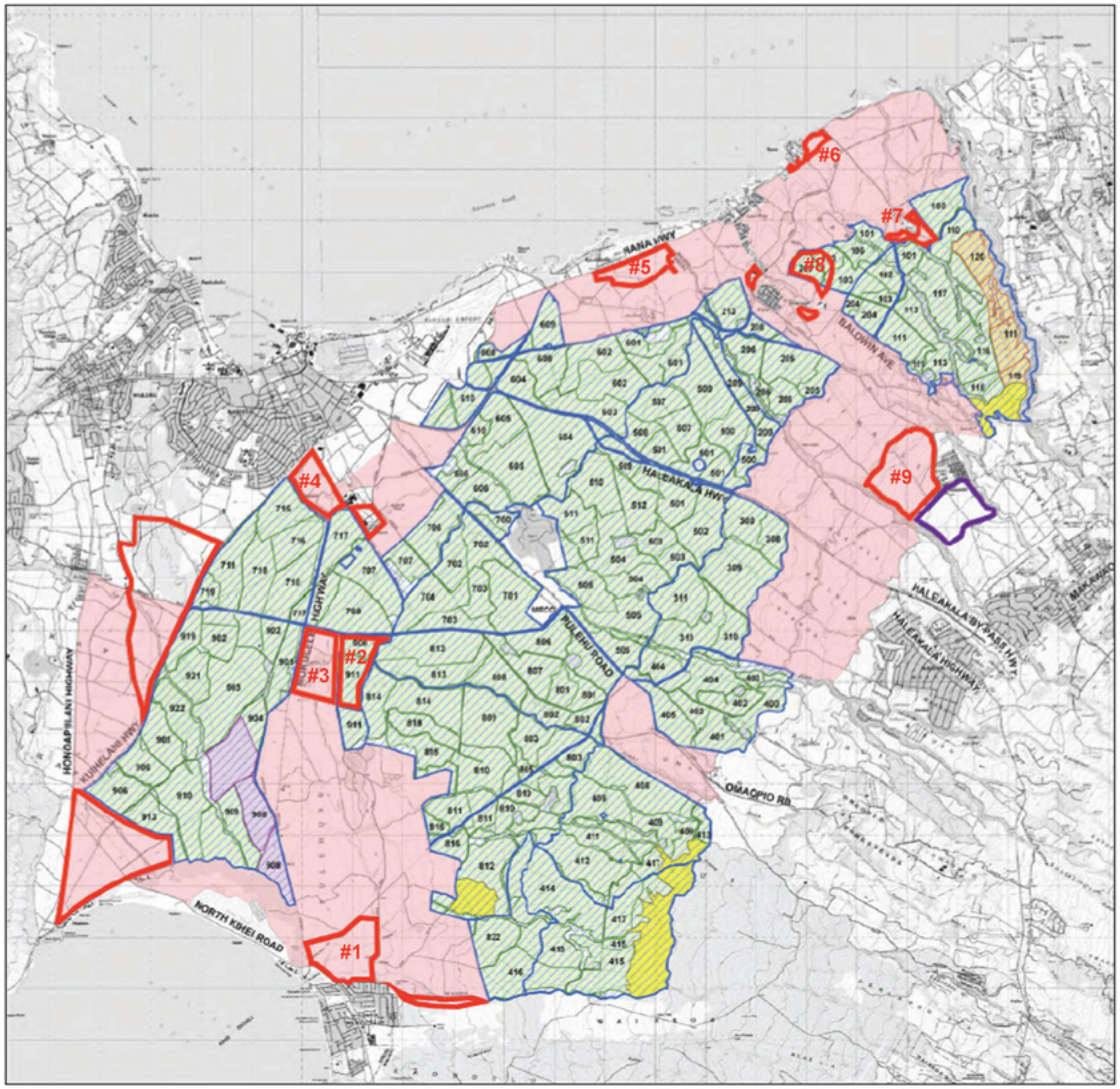
- How can private farm businesses have long-term access to land owned by A&B?
- Can some of the land be re-zoned to allow farmers to live on their farms? Could that include small farming communities like the plantation villages?
- What water rights will farmers have on these lands?
- Regenerative agriculture will use much less water than sugar cane. How can we guarantee watershed restoration post-sugarcane?
- Will A&B and HC&S continue to own the land and become a diversified multi-farm corporation?
- How will A&B work with the community and provide transparency regarding their farming and development agenda?
- Would A&B sell the land to a consortium of private buyers who are committed to regenerative agriculture? At what price?
- Can the land be held in perpetuity for regenerative agriculture, as a safeguard against development?
- How would the land be managed and distributed to farmers?

If A&B would sell the land at market value, a compelling alternative emerges: forming an island-wide Maui Farm Cooperative. Every citizen of Maui could be either a worker-member or consumer-member with voting rights, profit shares, access to healthy island-grown food, even health care. Under the umbrella of the Maui Farm Cooperative, independently managed divisions would oversee each main business branch: livestock, treecrops, vegetable crops, agritourism, composts, marketing, distribution, irrigation, education, and so on.

Sugarcane production ends this year. Maui needs agriculture jobs. The community has an opportunity to come together and help usher in a new era of farming on Maui. Cultivating beneficial relationships between stakeholders is the foundation for the success of any project. We look forward to hearing your stories, addressing your questions and concerns, and incorporating new ideas.



Legend
Agricultural Soils Productivity Rating
A (Excellent)
B (Good)
C (Fair)
D (Poor)
E (Very Poor)
Not Classified
Important Agricultural Lands
HC&S Reservoirs
Haiku Ditch
Lowrie Ditch
Kaunikoa Ditch
Hamakua Ditch
Rainfall Zones
Prevailing Winds
Land Use Zones
1 Excellent to Good soils, slopes 1-3%, irrigated Suited to: Annual and Perennial Crops Orchard Crops Commodity and Energy Crops Seed Crops Pasture
2 Excellent to Good soils, slopes 3-5%, minimal irrigation Suited to: Annual and Perennial Crops Orchard Crops Seed Crops Pasture
3 Fair, Poor to Very Poor soils, slopes 5%+, minimal to no irrigation Suited to Timber Pasture Habitat
4 Farm Hub Processing Centers Agricultural Sales Facilities Plant Nurseries
5 Agricultural Park Educational Facilities
6 Aquaculture Aquaponics
7 Small Farm Allotments Community Gardens
Conceptual Plan Draft
A&B IAL
Data Overlays Prepared by:
Permaculture Design International
for Maui Tomorrow
February 2016
HANA HWY
HALEAKALA HWY
BALDWIN AVE
MAKAWAO AVE
HALEAKALA BY-PASS HWY
HALEAKALA HIGHWAY
PULEHU ROAD
OMAOPIO RD
MOKULELE HIGHWAY
HONOAPIILANI HIGHWAY
KUIHELANI HWY
NORTH KIHEI ROAD
Haiku Ditch
Lowrie Ditch
Kaunikoa Ditch
Hamakua Ditch
Landfill Site
MECO
15"
20"
30"
40"
60"



Comparison Map Current (2010) HC&S Ag Lands and Lands Committed to Future Ag as IAL.

Current HC&S Lands in Ag Production: 35,000 Acres

HC&S Lands Designated as Important Ag Lands 2009 by LUC: 27,133 Acres

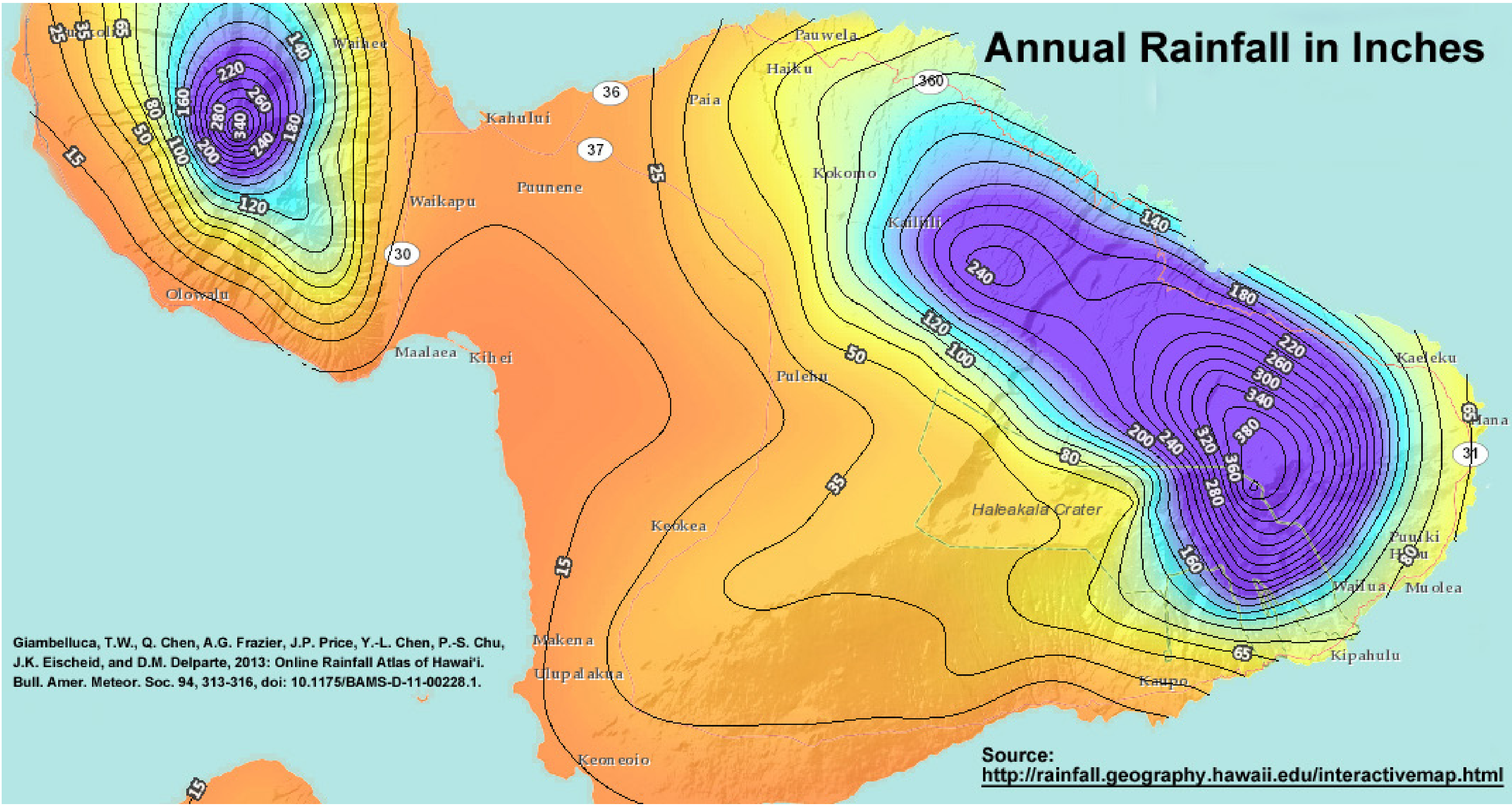
Current Water Use for 35,000 Acres from East Maui Sources 160mgd

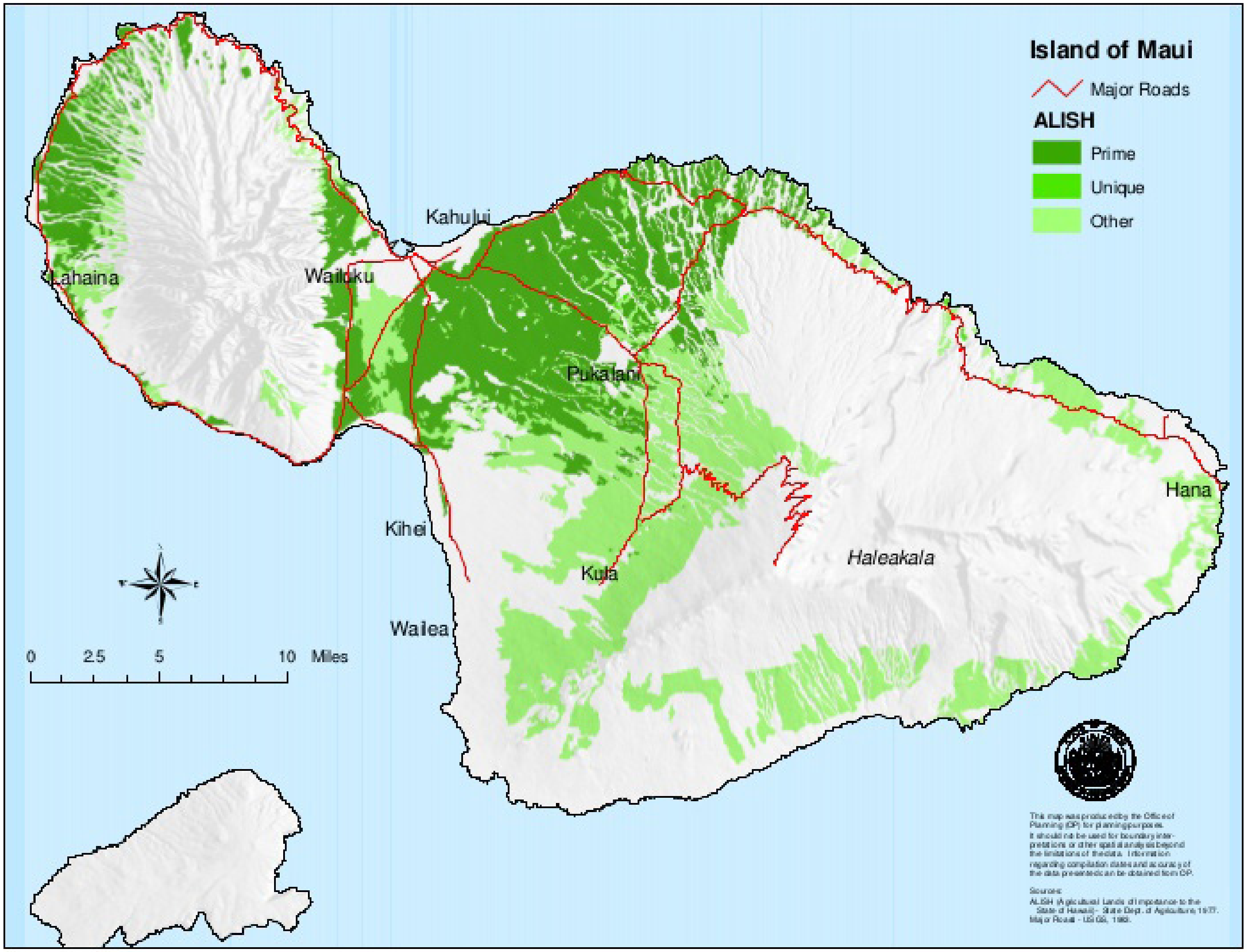
Legend

Crop Type

- Sugar
- Pineapple
- Seed Corn
- Pasture/ Other
- Proposed Important Agricultural Lands
- Existing HC&S Crop Lands not in IAL Boundary
- Development Areas Proposed During Maui Island Plan Process by A&B Inc. (Approx. 3,000 Acres)
- Proposed MLP Development Area

Map Source: HC&S IAL Application to LUC
Composite Map Provided by Maui Tomorrow May 2010


Annual Rainfall in Inches
Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013: Online Rainfall Atlas of Hawai'i. Bull. Amer. Meteor. Soc. 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1.
Source: http://rainfall.geography.hawaii.edu/interactivemap.html
Waihee
Kahului
Waikapu
Puunene
Olowalu
Maalaea
Kihei
Paia
Pauwela
Haiku
Kokomo
Kailiili
Pulehu
Keokea
Makena
Ulupalakua
Keoneoio
Haleakala Crater
Kaupo
Kipahulu
Wailua
Muolea
Kaeleku
Hana


Island of Maui
Major Roads
ALISH
Prime
Unique
Other
Kahului
Lahaina
Wailuku
Pukalani
Kihei
Kula
Wailea
Haleakala
Hana
0
2.5
5
10
Miles

Legume Trees with pods Edible to Livestock				
Common Name	**Species Name**	**Climate**	**Native Range**	**Nitrogen Fixation**
Carob	**Ceratonia siliqua*	Mediterranean	Mediterranean	No
Winter Thorn	**Faidherbia albida*	Arid to humid tropical lowlands and highlands	Africa	Yes
African Locust Bean	**Parkia biglobosa*	Semiarid to humid tropical lowlands	Africa	Yes
Palo Verde	**Parkinsonia aculeata*	Arid to semiarid tropics and subtropics	Americas	No
Monkey Bread	**Piliostigma thongii*	Semiarid tropics	Africa	Yes
Manilla Tamarind	*Pithecellobium dulce*	Semi-arid to humid tropical lowlands	Americas	Yes
Honey Mesquite	**Prosopis glandulosa*	Arid to semi-arid, subtropics to colA	North America	Yes
Kiawe	**Prosopis pallida*	Semiarid tropics	South America	Yes
Monkeypod Tree	*Samanea (= Albizia) saman*	Semi-arid to humid tropical lowlands	tropical Americas	Yes
Wild Cassia	*Senna singueana*	Semiarid tropics	Africa	No

**pods also edible by humans*

Adapted from Martin, Frank. Selecting the best Plants

Animal Feed (Grasses)								
Common Name	**Species Name**	**Food**	**Feed**	**Fiber**	**Const.**	**Fuel**	**Soil Amend.**	**Erosion Control**
Bermuda	*Cynodon dactylon*	0	5	0	0	0	0	4
Guinea	*Panicum maximum*	0	4	0	1	0	0	2
Kikuyu	*Pennisetum clandestin*	0	5	0	0	0	0	4
Napier	*Pennisetum purpureun*	0	5	0	2	1	0	4
Pangola	*Digitaria decumbens*	0	5	0	0	0	0	4
Star	*Cynodon nlemfluensis*	0	5	0	0	0	0	4
Sudan	*Sorghum sudanense*	0	5	0	2	1	0	1
Animal Feed (Legumes)								
Common Name	**Species Name**	**Food**	**Feed**	**Fiber**	**Const.**	**Fuel**	**Soil Amend.**	**Erosion Control**
Calliandra	*Calliandra calothrysus*		3					
Jack bean	*Canavalia ensiformis*	1	3	0	0	0	2	2
Leucaena	*Leucaena leucacephal*	4	4	0	2	4	4	3
Mesquite	*Prosopis sp.*	2	5	0	3	4	3	4
Mother-of-cacao	*Gliricidia sepium*	2	3	0	3	3	3	3
Tibet Tree	*Albizia lebbeck*		4					

Adapted from Martin, Frank. Selecting the best Plants

Fiber					
Common Name	**Species Name**	**Annual or Perennial**	**Growth Habit**	**Drought**	**Other Uses**
Abaca	*Musa textilis*	perennial	large herb	no	cord
Cotton	*Gossypium spp.*	annual	large herb	no	stuffing
Hemp	*Cannabis sativa*	annual	large herb	no	yes
Jute	*Corchorus capsularis*	annual	herb	no	cord
Kapok	*Ceiba pendandra*	perennial	tree	no	stuffing
Kenaf	*Hibiscus spp.*	annual	herb	no	cord, leaves
Mahoc	*Hibiscus tiliaceus*	perennial	tree	yes	no
Sisal	*Agava spp.*	perennial	herb	yes	cord
Baobab	*Adansonia digitate*	perennial	large tree	yes	clothing
Paper mulberry	*Boussingaltia*	perennial	large shrub	yes	clothing

From Toesnmeier, E. Carbon Farming Ch 22 industrial oils

Annual Biofuels Plants	
Latin Name	**Common Name**
Helianthus annus	Sunflower
Carthamus tinctorius L.	Safflower
Glycine max	Soybean
Cannabis sativa l	Hemp
Hibiscus cannabinus	Kenaf

Perennial Oil Biofuels plants				
Inedible oil yields compared				
Latin Name	**Common Name**	**Climate**	**Seed or fruit yield t/ha**	**Oil yield t/ha**
Jatropha curcas	Jatropha	Tropical lowlands, semi-arid to humid	1-15.0	0.3-5
Aleurites mollucanus	Candlenut	Tropical humid to semiarid	16	3
Ricinus communis	Castor bean	Tropics, subtropics, high or lowlands, semi-arid to humid	0.5-5	0.3-2.7
Pongamia pinnata	Pongamia	Subtropics, tropics, lowlands,highlands, humid	5-8.0	1.8
Simmondsia chinensis	Jojoba	Subtropics, arid to semi-arid	2.2-4.5	0.5-1.1
Azadirachta indica	Neem	Tropics, humid to semi-arid		0.5

Cover Crops

Common Name	Species Name	Adapt*	Propagation	Nitrogen Fixation	Erosion Control	Mulch	Ground Cover
Cowpea	*Vigna unguiculata*	I	seeds	4	3	4	4
Hosei	*Vigna hosei*	I,W	cuttings	4	4	5	5
Indigo	*Indigofera spp.*	I,W	seeds	4	5	3	5
Jack bean	*Canavalia ensiformis*	I,W	seeds	4	3	3	4
Lablab bean	*Dolichos lablab*	I,W	seeds	4	1-5	2	1-5
Perennial peanut	*Arachis spp.*	I	seeds, cutting	4	5	2	4-5
Sun hemp	*Crotalaria juncea*	I	seeds	4	3	4	3
Tinaroo	*Glycine wightii*	I,W	seeds	4	5	3	5
Velvet bean	*Stizolobium deeringianum*	I,W	seeds	4	5	3	5

Alley Cropping Fodder Trees

Common Name	Species Name	Adapt*	Alley Crop	Nitrogen Fixing	Erosion Control	Mulch	WindBreak	Shade
Agati	*Sesbania grandiflora*	I	5	3	4	2	1	1
Calliandra	*Calliandra calothrysus*	I,W	5	4	4	3	3	3
Horseradish tree	*Moringa oleifera*	I	4	0	1	2	0	1
Ice Cream Bean	*Inga edulis*	I,W	5	3	3	4	2	3
Leucaena	*Leucaena leucacephala*	I	5	5	2	3	1	1
Mother of cacao	*Gliricidia sepium*	I	4	4	2	3	1	3
Pigeon pea	*Cajanus cajan*	I	5	4	3	3	0	0
Tibet Tree	*Albizia lebbeck*	I,W						

*Key to adaptation: W= hot wet tropics; U= upland tropics, D= dry tropics, I = intermediate, neither too wet nor too dry.

Adapted from Martin, Frank. Selecting the best Plants

Specialty crops (beverages, oil, spices, sugar)			
Common Name	**Species Name**	**Annual/Perennial**	**Growth Habit**
BEVERAGES			
Cacao	*Theobroma cacao*	perennial	small tree
Coffee	*Coffea arabica, C. robusta*	perennial	small tree
Tea	*Camellia sinensis*	perennial	shrub
SPECIALTY OILS			
Tung	*Aleurites spp.*	perennial	tree
Ylang-Ylang	*Cananga odorata*	perennial	tree
SPICES			
Indonesian Cardamom	*Amomum cardamomum*	perennial	herb
Cardamom	*Elettaria cardamomum*	perennial	herb
Turmeric	*Curcuma domestica*	perennial	herb
Cloves	*Syzygium aromaticum*	perennial	small tree
Nutmeg & Mace	*Myristica fragans*	perennial	tree
Pepper	*Piper nigrum*	perennial	vine
Galangal	*Alpinia galanga*	perennial	herb
Ginger	*Zingiber officinale*	perennial	herb
Vanilla	*Vanilla fragrans*	perennial	vine

Arid/Semi-Arid adapted Multi-purpose windbreak species, Adapted from Elevitch, C. Multipurpose windbreak trees.										
Botanical Name	**Common Name**	**Mature Size (ft)**	**N-Fixer**	**Fruit/ Nut/**	**Fodder**	**Bee Forage**	**Wood/ Timber**	**Wind break**	**Growth Rate**	**Potentially Invasive**
Acacia koa	Koa	50-80'	Y		Y	Y	Y	Y	F	
Acacia confusa	Formosa Koa	50-80'	Y		Y	Y	Y	Y	F	
Acrocarpus fraxinifolius	Pink Cedar	80-160'					Y	Y	F	
Albizia lebbeck	Tibet Tree	25-35'	Y		Y	Y	Y	Y	M	Y
Aleurites moluccana	Kukui, Candlenut	50-80'		P	P			Y	M	
Anacardium occidentale	Cashew	35-40'		Y	Y		Y	Y	S	
Annona muricata	Soursop	<20'		Y				Y	S	
Araucaria bidwillii	bunya-bunya pine	90-120'		Y	Y		P		S	
Artocarpus heterophyllus	Jackfruit	30-70'		Y	Y		Y	Y	S	less drought hardy
Azadirachta indica	Neem	40-60			Y	Y	Y	Y	M	
Bambusa oldhamii	Oldhamii	40-60'		Y			Y	Y	M	
Casimiroa edulis	White Sapote	20-45'		Y			P	Y	S	
Ceratonia siliqua	Carob	45-55'		Y	Y		Y	Y	S	
Chrysophyllum cainito	Star Apple/Caimito	25-50'		Y				Y	S	
Cocos nucifera	Coconut	30-90'		Y		Y	Y	Y	S	less drought hardy
Eucalyptus cameldulensis	Red River Gum	80-120'				Y	Y	Y	F	Y
Eucalyptus sideroxylon	Red Iron Bark	50-60'				Y	Y	Y	F	Y
Eucalyptus robusta	Swamp Mahogany	80-120'				Y	Y	Y	F	
Gliricidia sepium	Madre de cacao	30-35'	Y		Y	Y	Y	Y	F	
Mangifera indica	Mango	80-120'		Y		P	Y	Y	S	
Manilkara zapota	Sapodilla	50-60		Y	Y		Y	Y	S	
Moringa oleifera	horseradish tree	30-45'		Y	Y	Y		Y	F	
Morus nigra	Mulberry	20-25'		Y	Y	Y		Y	M	
Pithecellobium dulce	Manila tamarind	35-50'	Y		P	Y	Y	Y	M	Y
Prosopis glandulosa	Honey Mesquite	20-30'	Y	Y	Y	Y		Y	M	
Pterocarpus indicus	Narra	90-120'	Y		P		Y	Y	M	
Senna siamea	Pheasantwood	50-60'			P		Y	Y	F	
Swietenia macrophylla	Mahogany	90-120'					Y	Y	M	less drought hardy
Tamarindus indica	Tamarind	80-100		Y	Y		Y	Y	S	
Thryostacys siamensis	Monastery Bamboo	20-45'		Y	P		Y	Y	M	

P=potential

Limitations of Livestock in Agroforestry				
Livestock Species	Damage Young Trees	Scratch or Dig	Silvopasture Only	Diverse Perennial Understory
Cattle	Yes		Yes	
Chickens		Yes	Yes	Yes^
Ducks & Muscovies				Yes^
Geese				Yes
Goats	Yes		Yes	
Hogs	Yes	Yes	Yes	Yes*^
Sheep	Yes		Yes	
Turkeys		Yes	Yes	Yes*

From Toensmeier, E.

Agroforestry Functions of Livestock						
Livestock Species	Mow & Graze	Clear Brush	Eat Bugs	Till	Weed Grass Only	Clean Drops
Cattle	Yes	Yes*				Yes*
Chickens	Yes		Yes	Yes		Yes
Ducks	Yes		Yes			
Geese	Yes				Yes	
Goats	Yes	Yes				
Hogs	Yes		Yes*	Yes	Yes*	Yes
Sheep	Yes	Yes*				Yes
Turkeys	Yes		Yes			

*Breed dependent
^Sequence and crop dependent

POTENTIAL FOOD CROPS FOR MAUI					
Grains					
CommonName	**SpeciesName**	**Annual/Perennial**	**Principal Nutrients**	**Yield (lbs/ac)**	**Water Use (ac. Ft/ac/yr)**
Amaranth	*A. cruentis A. hypochondr*	protein, starch	protein, starch	800	2
Corn, Maize	*Zea mays*	protein, oil, starch	protein, oil, starch	6,000-12,000	1-2.0
Pearl Millet	*Pennisetum americanum*	protein, starch	protein, starch	3,000-4,000	1
Quinoa	*Chenopodium quinoa*	protein, starch	protein, starch	900-1,200	0.8-1.2
Sorghum	*S. bicolor*	protein, starch	protein, starch	4,000-5,000	1-2.0
Legumes					
Common Name	**Species Name**	**Annual/Perennial**	**Principal Nutrients**	**Yield**	**Water Use**
Bean, common	*Phaseolus vulgaris*	annual	protein, starch	1,200-1,800	1.7-2.1
Chick pea, garbanzo	*Cicer arietum*	annual	protein, starch	800-2,000	0.5-1.0
Cowpea	*Vigna sinensis*	annual	protein, vit. B	1,000-3,000	1.0-2.0
Lablab	*Dolichos lablab*	annual	protein, starch	1,000-2,000	2.0-4.0
Lima bean	*Phaseolus vulgaris*	annual	protein, vit. B, starch	2,000-3,000	1.3-2.0
Mung bean	*Vigna radiate*	annual	protein, starch	300-2,000	1.2-1.7
Pigeon pea	*Cajunus cajan*	annual or weak perennial	protein	700	2.0-3.7
Roots and Tubers					
Common Name	**Species Name**	**Annual, Bi/ Perennial**	**Principal Nutrients**	**Yield**	**Water Use**
Cassava	*Manihot esculenta*	per. Grown as annual	starch	15,000	4.0-5.0
Jicama	*Pachyrrhizus erosus*	weak per. used as annual	starch, protein	10,000-14,000	N/A
Sweet Potato	*Ipomea batatus*	per. Grown as annual	starch, vit. C, maybe A	28,000-32,000	2.5-3.5
Fruit Vegetables					
Common Name	**Species Name**	**Annual/Perennial**	**Principal Nutrients**	**Yield**	**Water Use**
Chayote	*Sechium edulis*	perennial	tips high in vitamins, minerals	40,000-80,000	4.0-5.0
Eggplant	*Solanum melongena*	weak perennial	low nut. Value	15,000-30,000	1.5
Okra	*Abelmoschus esculentus*	annual	fair source of most nutrients	7,000-10,000	1.0-2.0
Pepper	*Capsicum annum*	weak perennial	vit. A & C	10,000-20,000	2.0-2.5
Pumpkin tropical	*Cucurbita moschata*	weak perennial	vit. A & C, seed high in oil & pro	9,000-11,000	1.7-2.4
Misc. Vegetables					
Common Name	**Species Name**	**Annual/Perennial**	**Principal Nutrients**		
Artichoke	*Cynara scolymus*	perennial		9,000-11,000	1.5-2.0
Asparagus	*Asparagus officinale*	perennial	vit. C	2,500-3,000	1.5-2.5
Tropical Fruit Crops					
Common Name	**Species Name**	**Annual/Perennial**	**Principal Nutrients**	**Yield**	**Water Use**
Avocado	*Persia americana*	perennial	oil	4,000-7,500	2.0-4.0
Breadfruit	*Artocarpus elastica*	perennial	starch	12,000-25,000	1.5-4.0
Carob	*Ceratonia siliqua*	perennial	starch	6,000-8,000	0.5-1.0
Citrus	*Citrus spp.*	perennial	vit. A & C	15,000-30,000	2.0-4.0
Mango	*Mangifera indica*	perennial	vit. A & C	20,000-40,000	5.0-9.0
Papaya	*Carica papaya*	perennial	vit. A & C	20,000-30,000	2.0-3.0
Tropical Nuts					
Common Name	**Species Name**	**Annual/Perennial**	**Principal Nutrients**	**Yield**	**Water Use**
Cashew	*Anacardium occidentale*	perennial	protein	800-1,500	1.0-2.5
Macadamia	*Macadamia spp.*	perennial	protein	2,500-3,000	3.0-4.0

General Report References

Maui County:
Maui General Plan 2030:
http://www.co.maui.hi.us/DocumentCenter/View/84679

County of Maui Website with links to General Plan 2030 as well as State and 9 County individual Community Plans:
http://www.co.maui.hi.us/index.aspx?NID=421

Maui Ag Design Conference Preliminary Report:
http://h-cx.com/Hawaii_Local_Exchange/Maui_Ag_Design_Conference_files/Maui%20Ag%20Design%20Conf%20-%20Preliminary%20Report.pdf

Maui water:
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An Appropriate Jobs Multiplier for the Hawaii Sugar Industry

The derivation of an appropriate jobs multiplier here follows the methodology of Hitch. * Hitch divides jobs created by the sugar industry in Hawaii into three levels:

(1) The direct jobs are those in the sugar industry itself.

(2) First round indirect jobs are those that are created by suppliers who service the sugar industry, such as local suppliers of fertilizer, herbicide, gasoline, mill equipment or machinery, or services such as construction, transportation, communications, legal, etc. These suppliers may service others besides the sugar industry, but at least part of their job is owed to sugar.

(3) Indirect multiplier jobs that are created. For example, when employees in categories (1) and (2) are paid, they spend most of their paycheck in the local economy. Those who supply those general goods and services therefore also benefit from the sugar industry.

Hitch then estimates that 35% of the money disbursed by a sugar plantation goes to the direct creation of jobs. Of the remaining 65%, he also assumes that about half becomes income to residents of Hawaii (firms or individuals) – about 32% of the direct disbursements of a sugar company, with 33% leaking out of state. This means that there are almost as many indirect jobs created by sugar as there are direct ones, 91% in fact (32/35 = 91).

The third category of indirect multiplier jobs can then be derived by resorting to the overall regional multiplier derived in Appendix II.

To summarize: Level 1: direct sugar job
Level 2: indirect sugar job Sub-total
Level 3: multiplier effect
1.00 .91 1.91 x 1.50 2.87
Subtracting the 1.00 for direct sugar jobs means that there are 1.87 jobs in Hawaii that are created indirectly for every job created directly by sugar itself. **

* Hitch (*op. cit.*), p.3. This multiplier was originally estimated by the Research Department of First Hawaiian Bank in 1961, and was published in a study entitled *The Impact of Exports on Income in Hawaii.*

** Hitch arrived at a number of 2.29 instead of 1.87, but that was because he used a regional multiplier of 1.72 instead of 1.50. As explained in Appendix II, today the regional multiplier might be smaller than it was in earlier, thus a more conservative number is adopted.

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