METABOLIC

REGENERATIVE AGRICULTURE

Framework for Fruit

AGRANA FRUIT

reNature.

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☑ *Essential Practice* ☑ *Additional practice*

EXECUTIVE SUMMARY

In this document, we summarize peer-reviewed research and advice from expert practitioners on how to transition fruit farming systems from conventional to regenerative agriculture. Growing fruit regeneratively requires strategies that restore soil fertility, improve water availability and increase functional biodiversity (the variety of life included on the farmland), while also increasing the farm's overall resilience to disruptions such as climate change. The advice provided in this report outlines essential actions that should be taken for a farm to be considered regenerative, as well as further actions that can provide added benefit. This is a broad framework, there is no one-size-fits-all approach that is appropriate for a holistic transition to regenerative farming.

GENERAL NOTES ABOUT REGENERATIVE AGRICULTURE FOR FRUIT

The transition from conventional to regenerative agriculture is a journey rather than a single action. Regenerative agriculture practices and agroecosystem services provided when farming in line with nature have recently been given scientific attention. Most of the practices we outline in this framework are not new, but rather aggregated from traditional knowledge of agricultural systems over millennia. Many of the recommended interventions take time to initiate and longer to see the effects – ranging from months to several years. The practices build upon one another and will require many years to realize full results. The overall goal of beginning a transition toward regenerative agriculture is to farm in a way that not only does less harm to the environment, but actually brings more life into it. To this effect, it's important to realize that the processes needed to reduce inputs such as synthetic fertilizers and pesticides must occur over time in order to maintain yield. In many conventionally operated agricultural systems, the soil has been depleted of organic matter and nutrients, and it will take years to build up enough soil health to fully enjoy the advantages of regenerative practices.

Fruit, more so than most crops, require high nutrient content in the soil or from synthetic fertilizers. For best results, especially in maintaining yields, the recommended actions should be carefully planned with advice from local experts (agronomists, pomologists, etc.). Fortunately, recent meta-analyses of regenerative practices show that in most cases, yields can be maintained throughout the conversion to a regenerative system. In addition, because many of these cropping systems inherently rely on functional biodiversity, there is often ample opportunity to produce secondary crops (or other co-products) and corresponding revenue streams. This can increase both the financial viability and resilience of the farming operation, but may also increase its complexity. Operational complexity and the requirement for specific knowledge should therefore be fully taken into account when planning and financing a transition to regenerative practices.

Farmers have expert knowledge of their land, so any transition toward a regenerative food system needs farmer input and ownership. It is important that farmers and farmworkers are given the opportunity to adapt these frameworks to their land, while maintaining the core principle of farming in line with nature. In order to use this framework to guide a group of farms through the transition to regenerative agriculture, farmers must be engaged and share knowledge and expertise about the unique characteristics of their farmland, crops, farm management practices, and business operations. Because many regenerative practices take more than one growing season to take effect, farmers will likely need funding and partners to help support them through the transition period.

ESSENTIAL AND ADDITIONAL REGENERATIVE PRACTICES FOR FRUIT

Through a literature search and expert practitioner review, we have compiled a list of the highest confidence regenerative agricultural practices for fruit. The practices listed in this framework are broken into two groups. There are essential practices that each farm should strive to accomplish on their journey toward regenerative agriculture, and there are additional practices that are not necessary but provide added benefits. The goal of these practices is to allow the farmer to produce nutritious fruit while restoring the natural environment. Regeneration of nature is accomplished by restoring soil fertility, increasing water retention of the soils, and producing healthy productive fruit. Alone, no single action will accomplish these lofty goals but with dedication to the implementation of an orchestrated plan, year by year, the farm will see improvements, build resilience and ecosystem services provided by nature will reappear. Under the heading 'Plan Development' on *page 29* there is detailed information on how to build out a plan and what metrics to consider. In the section titled 'Details on Crop Type Specific Implementation', which starts on *page 26*, there is more information on the variability between practices as well as the timescale for expected benefits. In the appendix, more details on the benefits for each action and where to find more information on them are provided.

The essential practices that should be implemented in concert are:

- ☑ **Avoid Bare Soil**
- ☑ **Cover Crops as Green Manure**
- ☑ **Minimize Soil Disturbance**
- ☑ **Living Fences/Hedgerows/Windbreaks**
- ☑ **Mulching with Organic Material**
- ☑ **Plant and Field Maintenance for Pest and Disease Prevention**
- ☑ **Match Irrigation Technique to Climate, Topography, and Water Availability**
- ☑ **Nutrient Analysis and Budgeting of Soil and Crop**
- ☑ **Prioritizing Perennial Plants**
- ☑ **Increasing Crop Biodiversity**

The practices that provide additional agroecological benefits (and in some cases income streams) but are not absolutely necessary for the transition toward regenerative agriculture are:

- ☑ **Livestock Integration**
- ☑ **Intercropping with Other Tree Species**
- ☑ **Increasing Percent of Natural/Semi-Natural Non-Crop Areas/Habitats**
- ☑ **Adding Stones and Branches to the Landscape**

☑ *Essential Practice* ☑ *Additional practice*

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KEY

EFFECTS

Increased Overall Yield

For example by enhancing root growth, nutrient availability and uptake, water storage, use efficiency, disease/stress pressure reduction.

Decreased Single Species Yield

The yield of individual species in multispecies agroforestry systems can be lower than in monocultures.

Increased Single Species Yield

Higher yield can be obtained through either increase in fruit set/size and/or increased photosynthetic activity.

Enhanced Nutrient Content

Increased nutrient levels in the fruit by way of the soil.

Nutrient Imbalance

Competition with other plants for soil resources can lower nutrient content within plants or soil (but not with annual crops and minimum tillage).

Enhanced Pollination

Habitat provision for diverse pollinator species.

Soil Erosion Mitigation

Decreased runoff preserves farms' soil while decreasing sedimentation and desilting costs.

Increased Beneficial Soil Microfauna Populations

Increasing soil organic matter, (specifically C and N pools) favour beneficial (rather than herbivorous) nematodes, keeping pathogens in control.

Additional Revenue Stream

Diversification of income opportunities with increased farm resilience.

Increased Water Availability

Rehydration of the overall soil profile and/or capturing surplus run-off increases the water potential of the agroecosystem.

Protection Against Extreme Weather Events

Higher agro-ecosystem resilience and faster productive recovery compared to monocultures.

Weed Suppression

Suppression of spontaneous vegetation, reducing weed pressure to tree crops.

Reduced Pest Burden

Habitat provision for functional elements of biodiversity, specifically natural predators of pests.

Increased Pest Potential

Greater habitat provision serves as a host for potential pest populations.

KEY

PRACTICE CATEGORY

Essential practice
Essential practices are the initial actions a farmer can take for a farm to begin the regenerative agriculture process, there must be a plan in place that incorporates all of the essential practices outlined in the framework.

PRACTICE DETAILS

Indicators
Possible state measurements for the practice.

Effects
Benefits and tradeoffs associated with a practice.

Cost considerations
Possible labor or financial costs associated with implementation of a practice.

SOCIAL POINTS OF VIGILANCE

Labor Risks
- Youth labor risk.
- Risk of underpayment (below living wage).
- Gender wage gap risk.
- Work safety (fatal/non-fatal accidents in the workplace) risk.
- Risk of exceeding working hours.
- Risk of preventing collective bargaining potential.

Access Considerations
- Lack of equitable to access to knowledge/expertise potential
- Lack of equitable access to equipment/ inputs potential

Social Considerations
- Neighbor/peer pressure.
- Legal/permitting challenges.
- Social pressure from delayed benefits.

HOW TO USE THE FRAMEWORK

The framework provided below summarizes essential regenerative agriculture practices for fruit crops. The actions selected are widely applicable across all climates and fruits within each typology. On *page 26* there is more detailed guidance for three fruit typologies: tree fruit, bush fruit, and ground fruit. To tailor the framework to a farmer's specific needs, please follow the guidelines below. We have outlined the essential practices, the additional practice, and how to develop a plan to begin the journey toward a regenerative farming operation. In order for a farm to begin to regenerate the land, there must be a plan in place that incorporates all of the essential practices outlined in the framework. When biodiversity, soil organic matter, soil fertility, water retention, and other outcome indicators are increasing on the farm, it can truly be deemed regenerative.

EVERYONE: CO-DEVELOP A PLAN

The most important first step when beginning a transition toward regenerative agriculture is to build a plan with the farmer. Many of the practices require local knowledge of plants, climate, topography, soil food webs, pest pressure, and cropping patterns. This often means that partnering with local supporting organizations (such as those listed at *https://regenerationinternational.org/*) is essential. The plan should be something that farmers have a say in, have help in developing, and that covers the essential practices for each fruit type outlined in the framework. Furthermore, many of the practices require additional labor or time to observe and react to their effects on the farm. It is important that these dimensions are accounted for in the farm plan. There is an outline for plan development on *page 29* of this document.

FARMERS AND COOPERATIVES

As a farmer, you are familiar with your land as well as the management practices used on your farm. In the framework below, we have outlined many potential regenerative farm management practices for each of the three crop typologies. The goal is to use this information to help you develop a plan for your farm to transition toward regenerative agriculture.

1. Read over the essential practices, these are the practices that should be your first priority for implementation.
2. Partner with an agronomist or local NGO begin to develop a farm plan.
3. Identify if there are any of the practices that are already in place on your farm.
4. Identify how these practices may vary depending on climate, crop type, and farm management style. There may be further research and consultation required if there is considerable variability for a specific practice. Utilize the details about the essential practices for your particular fruit type (tree, bush, ground).
5. To begin development of the farm plan, select a combination of essential practices to implement that fit your farm's profile and needs. Develop an implementation plan that takes into account the time needed for each action as well as the climate- and crop- specific requirements of your farm (see Co-Develop a Plan section).
6. Make sure to be realistic about your plan to protect yield: the plan should not immediately reduce the use of synthetic pesticides and fertilizers, for example, but instead gradually wean the farm off of these inputs while enhancing functional biodiversity and promoting agroecological practices in order to deliver important agroecosystem services.
7. Identify, solicit, or otherwise secure any necessary funding and/or equipment for the transition period outlined in your plan.
8. When beginning implementation of the plan, remember that it is okay to start with a portion of the farm and to ease into the transition slowly in order to protect your yield and expand these practices slowly and carefully.

BUYERS

As buyers, you have the opportunity to help usher in the transition toward regenerative agricultural systems. The following framework should be used as a reference to help guide suppliers and farmers in their transition toward regenerative agriculture. The framework provides a shared definition and understanding throughout the fruit value chain about which practices are regenerative, what the most essential practices are, and where to seek further information.

1. Become familiar with the language, especially those of the essential practices.
2. Work to understand what regenerative practices the farms in your supply chain may already have adopted and make context-specific plans to complement these existing practices.
3. It is useful to have on the ground expertise for planning agricultural transformation. Seek the support of local NGOs, co-ops, or agronomists.
4. Explore ways to build in mechanisms for transition funding to help farmers maintain viability through any disruption to yield caused by the transition to the regenerative practices outlined below, especially the essential practices.
5. Make sure to work with farmers and to realize that the transition to regenerative farming is a *long-term commitment and that transitioning systems too quickly (especially moving away from synthetic pesticides and fertilizers that the soils have grown accustomed to) will be risky for the farmers' livelihoods.*

AGRONOMISTS

As agronomists, there are certain farm management practices that have become the norm in the past 30-50 years that regenerative agriculture conflicts with. Use this framework as a starting point to guide your understanding of regenerative agriculture for fruit production.

1. Identify which practices (particularly essential practices) you're already familiar with and which ones you may need more information about.
2. Identify the crop type details for the essential practices.
3. Use the framework as a guide to help farmers build a plan for their regenerative transition. The frameworks are a guide for making informed decisions in the transition toward regenerative agricultural practices by taking on the essential practices first, and then companion practices with those and slowly weaning them off synthetic fertilizers and pesticides until they start to see the full benefits of the regenerative agricultural practices.
4. Tailor practices taking into account local climate, topography, and species when creating a plan for regenerative farm management.
5. Try to find local resources to determine what types of cover crops, native flowers, and potential livestock integration possibilities are available and useful in your area.
6. Identify if there are local NGOs and hubs for exchange of information.

REGENERATIVE PRACTICES FOR FRUIT

PRACTICES

PRACTICE

AVOID BARE SOIL

Description

Ensuring all ground in the cropland is covered with vegetation.

Avoiding bare soil is an essential prerequisite for achieving compounded success in a regenerative agriculture system. Avoiding bare soil by maintaining consistent coverage with living vegetation or mulch applies to all cropping systems.

Actions related to this practice

- 'Cover Crops as Green Manure'
- 'Mulching with Organic Material'
- See appendix sections 1, 2 & 3 for more details

Applicability

This practice is important to implement in **all cases.**

	Percent of farm w/ vegetation cover
	Requires additional labor
	Requires seed or organic matter inputs
	Improves soil structure
	Increases system resilience
	Increases functional biodiversity & the provision of agroecosystem services
	Improves water filtration
	Increased multispecies yield

PRACTICE

COVER CROPS AS GREEN MANURE

Description

A functionally diverse mix of ground cover vegetation (perennial/annual; leguminous & otherwise) can be used as a mulch through cut and drop mechanisms or through natural freezing/decomposition cycles in temperate climates (or a combination of both).

One particular method for avoiding bare soil in a cropping system is to use cover crops as green manure. As described above, avoiding bare soil is crucial for compounded success in a regenerative agriculture system, and maintaining a system of diverse vegetation can further boost these benefits. Cover crop mixes consisting of eight or more different species deliver the highest agroecological benefits. Determining cover crop seed mix is a site-specific practice and requires some specific considerations. There should be a mix of perennials and annuals. Perennials provide permanent ground cover with deep living root systems and arbuscular mycorrhizal fungi for nutrient exchange. Annual crops are often good green manures as they grow rapidly, and when cut quickly return their nutrients into the soil.

Leguminous cover crops are especially important as they work with bacteria on their roots to turn atmospheric nitrogen into accessible nitrogen in the soil (a process called nitrogen fixation). There is wide variation in the best types and combinations of cover crops because different species have different rooting shapes and depths, as well as different above-ground plant architectures. In this way, they can complement each other by optimizing the photosynthetic activity per square meter, and concentrating different types of nutrients in their tissues. Feeding a "mixed and balanced diet" to the soil leads to the best results. To plan a cover cropping system for your farm, consult an expert, reach out to academic extension communities, or use *decision support tools* (like *cover crop calculators*) to determine the right plan.

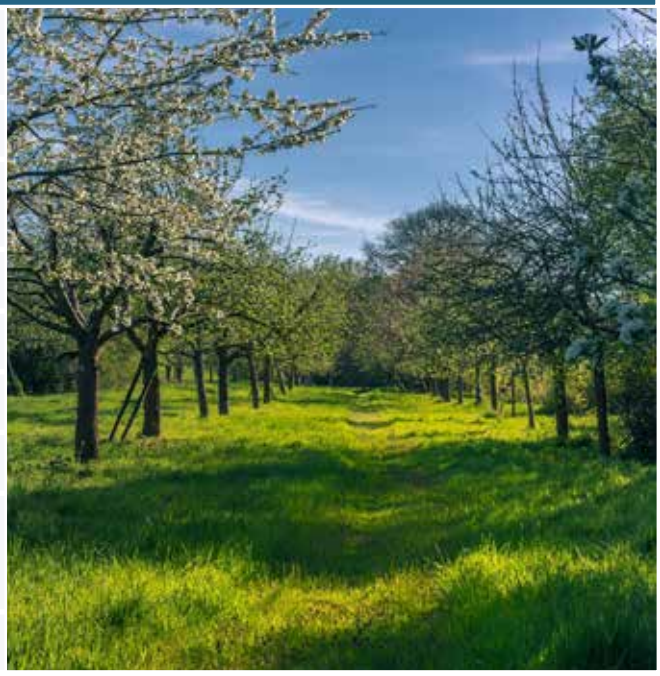
Actions related to this practice

- 'Mulching with Organic Material'
- 'Nutrient Analysis and Budgeting of Soil and Crop'
- See appendix sections 1, 3 & 5 for more details

Applicability

This practice is important to implement in all cases, and it is important to have legumes in the mix for N fixing.

	Percent of farm w/ vegetation cover, nutrient content of soil
	Requires additional labor
	Could require additional machinery (to cut & drop)
	Requires seed or organic matter inputs
	Improves soil structure
	Increases soil organic matter
	Increases system resilience
	Increases the provision of agroecosystem services
	Increases functional biodiversity



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PRACTICE

MINIMIZE SOIL DISTURBANCE

Description

Reduce tillage and if possible, eliminate tillage from the cropping management system.

The main approach to minimizing soil disturbance is through reducing and if possible, eliminating tilling and ploughing from the cropping system. The fewer passes per year the soil has of tillage, the more the soil is able to maintain its structure. Typically, in tree cropping systems, tillage occurs in the strips between the trees: known as "strip tillage". Reducing soil disturbance could mean shallower tillage depths and fewer cultivation passes. To access optimal results from this practice farmers should eliminate tilling all together in favour of no-till practices. In an orchard, the most appropriate tillage reduction will depend on the specific context.

Some examples are:

- Shallow cultivation bordering cropee lines, and no-till on the alleys. This is a way to couple the benefits of both approaches. Shallow cultivation next to crops breaks the soil capillarity preserving moisture in the ground, encourages deeper root growth, and minimizes competition with spontaneous vegetation. This is based on the same principles of the strip till approach for regenerative annual crop production. The non-cultivated part works as a natural buffer of soil creation, nutrient cycling and water regulation. The choice of perennial covers with a deep root system is of great importance, because they can intercept all the nutrients leached off the cultivated surface.
- No-till, coupled with a ground cover to provide organic mulch material to crop rows provides stacked benefits for soil nutrients and other agroecosystem services.

Actions related to this practice

- 'Nutrient Analysis and Budgeting of Soil and Crop'
- See appendix section 3 for more details

Applicability

This practice is important to implement in **all cases.**

	Frequency of tillage, soil organic carbon
	Could require additional machinery (ex. no till drill for establishment of living ground cover)
	Reduces overall costs related to ploughing/ tilling
	Improves soil structure
	Increases system resilience
	Increases functional biodiversity & the provision of agroecosystem services
	Improves water filtration

PRACTICE

LIVING FENCES/HEDGEROWS/WINDBREAKS

Description

Planting hedgerows or windbreaks that are functionally diverse (as many species groups included as possible) and are planted in a somewhat interconnected fashion around the cropland.

Hedgerows are common ecological infrastructure elements for orchards to protect the crops from wind and prevent erosion. For this action, instead of recommending single species hedgerows, instead we recommend multispecies windbreaks which can be called "living fences". These species should be carefully chosen for each system depending on the climate, water availability, topography, nearby natural habitats, and species interactions, and the planting density depending on size of the field. To create an integrated farm design, landscape elements are joined together to create an ecological network.

The living fences should include different strata of plant species: flowers, hedges, shrubs to provide functionally diverse habitat for pest predators, and pollinators. Wind can be a critical factor for fruit cultivation, especially in wind-characterized landscapes and areas where wind blasts might carry salt or sandy particles. Selecting plants specifically targeted for windbreaks is fundamental in reducing plant environmental stress and improving yields in wind prone environments.

Actions related to this practice

- 'Prioritizing Perennial Plants'
- 'Increasing Percent of Natural/Semi-Natural Non-Crop Areas/Habitats'
- See appendix section 2 for more details

Applicability

To create a multi-beneficial functional biodiversity area on the border of cropping areas, a long term solution to predator/pest interactions and to provide functional biodiversity and pollinators without dedicating too much land to natural areas.

	On farm biodiversity, soil biodiversity, presence/ absence of landscape elements
	Requires species specific knowledge
	Requires additional labor
	Requires time to see benefits (1-5 years)
	Requires seed or organic matter inputs
	Requires site specific planning
	Increases functional biodiversity & agroecological system services
	Increases system resilience
	Decreased Single Species Yield & increased multispecies yield

PRACTICE

MULCHING WITH ORGANIC MATERIAL

Description

Using organic plant material (i.e. straw, bark, leguminous pods, biochar) as ground cover.

Organic mulch is any material that comes from a living plant and it is laid on the soil to provide nutrients and protection. Over time, mulching with organic material is a way of building up the nutrient content of the soil and reducing synthetic fertilizer inputs. Combine this practice with nutrient management and monitoring, no-till practices and cover cropping achieve compounded benefits. Mulching with organic material simulates the natural process of organic matter deposition and accumulation. When choosing what to plant material to mulch with, it is important to distinguish between herbaceous or woody material and to determine which the nutrient content of the plant material (i.e. legume pods are high in nitrogen and release it slowly into the soil, woodchips stimulate mycorrhizal activity, etc.). Depending on the plant origin and nutrient composition of the mulch, it can provide different benefits over longer or shorter periods of time. The decision of what to mulch with is significant and should be carefully planned (preferably with the advice of experts) for your specific tree cropping system to avoid undue risks such as inadvertently changing the soil pH. Organic mulch can be produced on site: cut cover crop can be accumulated next to the production crop, and this activity is easily mechanized through the use of common farm machinery (i.e. a rotary rake or side-delivery flail mower). Also a wood shredder or flail mower with collector are just two of the ways to mechanize the process of mulching with woody biomass.

Actions related to this practice

- 'Avoiding Bare Soil'
- 'Cover Crops as Green Manure'
- 'Nutrient Analysis and Budgeting of Soil and Crop'
- See appendix sections 1, 3, & 5 for more details

Applicability

You need to cover bare soil, prevent water evaporation, and enrich the soil with nutrients to replace synthetic fertilizer inputs. This action works particularly well when monitoring nutrient input and selecting appropriate nutrient inputs at the right time.

	Soil organic carbon, presence/absence of mulch
	Requires additional labor
	Requires seed or organic matter inputs
	Increases soil organic matter
	Improves water filtration
	Increases functional biodiversity & the provision of agroecosystem service
	Increases system resilience
	Increased single species yield

PRACTICE

PLANT AND FIELD MAINTENANCE FOR PEST AND DISEASE PREVENTION

Description

Following best practices for crop maintenance (i.e. pruning (removal of infected parts of tree and residuals), harvesting (ex. years with low product price, fruit left on tree, substrate for diseases) and inspecting before applying biological control) and to prevent the spread of disease by disposing of these byproducts carefully.

Approaching best practices from a regenerative point of view means fine-tuning them to the interaction with other biotic and abiotic components. To best implement this practice, it is essential to have knowledge of local disease vectors and pest pressures. This is an ongoing process of observation and monitoring for pest and disease pressures, tailoring application of synthetic pesticides based on need rather than a schedule and replacing synthetic pesticides all together with biocontrol agents. Prevention of pest issues is easier and more effective than treating the issues once they've become a chronic problem. Pruning diseased branches and removing them from the system is one example of a field maintenance best practice. Additionally, removing all the fruits left on trees/shrubs or on the ground after harvest is a field maintenance best practice as it prevents larvae from maturing. Livestock integration, for example, is a way of implementing these sanitary practices as livestock eat discarded fruits that otherwise would provide breeding habitat for pests. Modes of increasing functional diversity within the cropping system provide a boost to natural predators to balance pest populations.

Best management practices are incredibly site and crop type specific and advice from an agronomist is essential in providing initial guidance on how to implement best practices on the farm. One major example: air. Excessive humidity and poor aeration are major disease sources in many climates. Reinterpreting conventional pruning systems with a focus on maximizing air flow and circulation, coupled with adapted plant genetics and appropriate nutrition, makes for a set of highly effective tools. Context-appropriate management is the best pest-prevention strategy.

Actions related to this practice

- 'Match Irrigation Technique to Climate, Topography, and Water Availability'
- 'Livestock Integration'
- 'Increasing Percent of Natural/Semi-Natural Non-Crop Areas/Habitats'
- See appendix section 4 for more details

Applicability

Best practices for disease and pest prevention should be implemented in all fruit cropping systems. This is a critical measure for success elsewhere (ex. won't reap benefits from increased biodiversity/soil management without best practice pest prevention techniques).

	Presence/absence of a best practice plan, pesticide input value
	Requires additional labor
	Requires species specific knowledge
	Requires site specific planning/observation
	Synchronize inputs/management practices with crop needs
	Increased overall yield & Increased single species yield
	Increasing system resilience

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PRACTICE

MATCH IRRIGATION TECHNIQUE TO CLIMATE, TOPOGRAPHY, AND WATER AVAILABILITY

Description

Using resources to determine the best type of irrigation system (i.e. drip irrigation) for the climate and field type. Additionally, using simple agronomic tools like FAO's Cropwat and tensiometers can help to ensure proper watering techniques are implemented.

Water design is site specific, but there are tools and resources that farmers can employ to ensure the water management practices best match the climate, topography, and water availability. The site design will depend on what the water inputs look like, and what the water input needs of the crops are. Both of these aspects should be monitored and measured and there are simple tools (i.e. sensors, tensiometers) to be able to do so. Matching the water use with the crop needs includes tracking and monitoring water source availability and overall water use on the farm through water meters. Irrigation type should be matched to these needs, the most efficient being drip irrigation (as compared to sprinklers and area flooding). Using a system that does not irrigate when it is raining provides the most efficient use of water.

Decision support tools like Cropwat and Aqaucrop (both free from FAO) can help to determine whether the water inputs are matching the crop needs. Fed with climate, soil and crop data, such tools can calculate a crop's water uptake and irrigation needs through the season, ensuring water-use maximization and product quality. Optimal irrigation management is a fundamental part of optimal nutrient management. Fertirrigation approaches (i.e. the application of fertilizer through irrigation) which minimize nitrogen application to match plant requirements, while targeting a complete mineral nutrition, result in a balanced vegetative growth and reduced disease pressure.

Actions related to this practice

- 'Nutrient Analysis and Budgeting of Soil and Crop'
- 'Minimize Soil Disturbance'
- 'Avoid Bare Soil'
- 'Cover Crops as Green Manure'
- See appendix section 6 for more details

Applicability

Should be applied in all cases and given priority if water availability is of concern in the region.

	Irrigation quality and quantity, presence/absence of tensiometers, water runoff quality
	Requires additional labor
	Could require additional machinery (irrigation system, sensors)
	Requires site specific planning/observation
	Synchronize inputs/management practices with crop needs
	Improves water filtration
	Increased overall yield & Increased single species yield
	Increasing system resilience

PRACTICE

NUTRIENT ANALYSIS AND BUDGETING OF SOIL AND CROP

Description

Keeping track of nutrient content in the soil and applying inputs like synthetic fertilizers only when they're needed.

Nutrient budgeting means comparing all the nutrient inputs (i.e. synthetic fertilizer, manure, etc.) to the nutrient outputs (i.e. sold crops, leaching, volatilization) at a farm-level. As a sort of balance sheet, this allows the minimization of waste and optimization of inputs. Keeping track of the nutrient content of soil (through soil testing) allows the fine-tuning fertilization inputs to the actual plant needs. Optimizing inputs has multiple benefits: from produce-use cost reductions to plant health. In the best case scenario, fertilization protocols are not fixed, but continuously adjusted through the season according to the feedback given by plant physiology. Understanding what the limiting nutrient is, at each fruit growth stage, permits the farmer to address root cause of nutrient deficiencies with targeted nutrition.

Proper nutrition acts on plant physiology, enhancing growth and reducing both biotic (pests) and abiotic (i.e. drought, frost, salinity) stresses. The correct nutrition management scheme can decrease the amount of simple sugars and soluble amino acids within the plant sap, making it more resistant to soil-borne pathogens and insects with simple digestive systems (like larval and sucking organisms). Working in synergy with other regenerative practices that are building soil organic matter over time, the plant will start absorbing more nutrients in the form of microbial metabolites, boosting the overall immune system. Soil measurements to be aware of in particular that help with nutrient budgeting are soil organic matter measurements as well as nitrogen and phosphorus soil testing.

Actions related to this practice

- 'Avoid Bare Soil'
- 'Cover Crops as Green Manure'
- 'Minimize Soil Disturbance'
- 'Mulching with Organic Material'
- 'Increasing Crop Biodiversity'
- 'Livestock Integration'
- 'Intercropping with Other Tree Species '
- See appendix section 5 for more details

Applicability

Nutrient analysis and budgeting should be implemented in all tree cropping systems.

	Fertilizer load, presence/absence of nutrient measuring, N, P, K measurements
	Could require time to see benefits (1-5 years)
	Requires additional labor
	Could require additional machinery (sensors)
	Requires species specific knowledge
	Requires site specific planning/observation
	Synchronize inputs/management practices with crop needs
	Increased overall yield & Increased single species yield
	Increasing system resilience

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PRACTICE

PRIORITIZING PERENNIAL PLANT

Description

Planting permanent ecosystems on the farmland.

Many fruit crops are perennial which enables the creation of complementary perennial plants. Perennial plants help to store carbon in the soil and develop intricate, permanent roots that build soil structure. Many fruit crops are already perennial plants and in this case it's essential to plant complimentary permanent plants into the system that help maintain a yield, provide soil nutrition, and homes for pollinators as well as pest predators.

Actions related to this practice

- 'Cover Crops as Green Manure'
- 'Mulching with Organic Material'
- 'Increasing Crop Biodiversity'
- 'Intercropping with Other Tree Species '
- 'Living Fences/Hedgerows/Windbreaks'
- See appendix sections 1 & 2 for more details

Applicability

Adding perennial plants into the farm landscape.

	Percent of farm under perennial cultivation
	Requires seed or organic matter inputs
	Improves soil structure
	Increases system resilience
	Increases functional biodiversity & the provision of agroecosystem services
	Improves water filtration

PRACTICE

INCREASING CROP BIODIVERSITY

Description

Increasing the genetic and species diversity of cultivated crops by including different varietals and crop species when possible.

By increasing the genetic and species diversity (overall increasing functional diversity) there is the potential to increase the types of crops harvested as well as the overall on farm biodiversity. For example, in an already-existing orchard, integration with different woody and herbaceous crops can happen in different modalities increasing the functional diversity of the orchard, including different types of trees is important for preventing pest crises. One way to do this is through the diversification of cultivars. If there is a pattern of trees on the farm of crops being lost to disease or chronic pest problems, this is a good sign that diversification of tree fruit species would provide beneficial pest management effects.

Actions related to this practice

- 'Nutrient Analysis and Budgeting of Soil and Crop'
- 'Prioritizing Perennial Plants'
- 'Intercropping with Other Tree Species'
- See appendix sections 1 & 5 for more details

Applicability

Whenever possible, in **all cases.** Especially if consistent pest and disease issues are present on the farm.

	Number of cultivated crops and varieties
	Requires seed or organic matter inputs
	Improves soil structure
	Increases system resilience
	Increases functional biodiversity & the provision of agroecosystem services
	Improves water filtration

PRACTICE

LIVESTOCK GRAZING

Description

Having sheep, goats, a chicken tractor, hogs, or cattle graze the field, particularly after the harvest is finished.

Animals catalyze ecological processes, fast-track the cycling of nutrients and organic matter, control weed and pest pressure while building soil and provide a potential income stream. In tree cropping systems, there is a minimal risk of the animals impacting the fruit as long as the fruit trees are mature. In bush fruit systems it is recommended to avoid cattle and goats, but sheep and poultry grazing work well. Besides constituting alternative income streams, one of the main advantages of integrating animals in the system is the "sanitation service" they provide, by feeding on crop residues and breaking pest cycles. Small animals (like poultry) can be integrated in any system, and easily confined within fences or mobile structures known as chicken tractors (the latter offer the best results in terms of soil management). Medium-sized grazers (like sheep) are typical of many fruit producing landscapes, especially where trees are structured in a way not to have low-hanging fruits. Espalier-like tree structures, where branches grow horizontally along the tree line, make for the easiest integration of any kind of animal in the orchard system. Electric lines can easily confine animal activity within the alleys. A farmer will benefit from the nutrient input and sanitation services from livestock integration in particular after harvest when there are fallen fruits potentially harbouring pest larvae. It is possible to reap benefits from this practice all season long for tree crops as long as sapling trees are protected from grazing animals. Additionally, grazing livestock on the farm provides the farmer with an additional income stream The livestock that are integrated in the system can belong to the farmer themselves or neighboring farmers in collaboration.

Actions related to this practice

- 'Plant and Field Maintenance for Pest and Disease Prevention'
- 'Nutrient Analysis and Budgeting of Soil and Crop'
- 'Mulching with Organic Material'
- See appendix section 7 for more details

Applicability

It's possible to either add animals to the cropping system or there are animals nearby that can benefit from an area to graze. This practice sees the most benefit after the harvest is complete but can be beneficial at any stage.

Soil Organic carbon, presence/absence of livestock

Requires additional labor

Requires species specific knowledge

Requires site specific planning

Increases soil organic matter

Increasing functional biodiversity

PRACTICE

INTERCROPPING WITH TREES

Description

Establishing an agroforestry system: including a variety of tree species (both crop and otherwise).

Depending on the shade tolerance of the crop, adding tree species into the crop system can be very beneficial for soil health, increase functional biodiversity, and add additional revenue streams to the farm. Integrating multiple levels of perennial woody and herbaceous species maximizes the photosynthetic capacity per unit of surface, combining production with the provision of a broad array of ecosystem services. The type of climate and ecoregion is a strong indicator of best practices in the design and management of integrated perennial systems and extension and agronomy professionals should help with these system decisions. The root systems of the trees are important to consider to avoid competition if water availability is of concern. In these cases, site specific and species specific knowledge is crucial for intercropping with multiple tree species to avoid yield deterioration. An example of an additional revenue stream would be fast-growing timber trees that can be established between fruit trees, even when space availability is a concern. Pruned high to maintain a "tall pole structure", their thinned canopy can still let enough light pass for fruit development, while effectively sheltering the produce from extreme weather events.

Intercropping with trees gives the advantage of tailoring the system to specific needs (e.g. fertilization of cash fruit crops through nitrogen-rich prunings of "sacrifice" species, integration of animal diet with nutrient-rich fodder, etc.). A broad array of design examples and global networks of experts can cover every context and situation. Orchards planned in this way are easily adaptable to local machineries and technologies.

Actions related to this practice

- 'Mulching with Organic Material'
- 'Nutrient Analysis and Budgeting of Soil and Crop'
- Prioritizing Perennial Plants'
- See appendix sections 1, 2, & 5 for more details

Applicability

Agroforestry systems provide benefits in soil, weather protection, but also provide shade. If dappled shade is not a concern, or if trees in an orchard system are being lost to disease or pests or have aged out of the system.

	Number of non-primary crop trees on farmland, on farm biodiversity
	Requires additional labor
	Requires time to see benefits (3-5 years)
	Requires site specific planning
	Requires seed or organic matter inputs
	Requires species specific knowledge
	Increasing functional biodiversity & agroecological system services
	Increasing system resilience
	Decreased single species yield & Increased overall yield

PRACTICE

INCREASING PERCENT OF NATURAL/SEMI-NATURAL NON-CROP AREAS/HABITATS

Description

Utilizing part of the cropland as a natural (native plant) habitat, without crops.

The goal of this practice is to take farmland that is not profitable and to bolster agroecosystem services while sacrificing yield in the short term for long term yield increase over the entire land. The amount of cropland that is converted into natural/semi-natural habitats ranges and should be allocated based on site specific assessments. This practice, also known as "rewilding", does not provide yield of any kind to the farmer and therefore it is not a practice that should be implemented when the farmland is fertile and the crops are mature and are producing a profitable yield. However, if parts of the field are not providing yield and instead there are chronic pest management issues, converting a portion of the orchard to natural habitat is a way of increasing the functional biodiversity and agroecosystem services of the entirety of the cropland. Consulting a local conservation-based NGO is the best way to approach this action. Typically (including living fences) 3-10% of a cropland is the ideal amount to remove from production. In larger woody patches natural pest enemies reproduce and thrive, while narrower herbaceous strips serve as "insects highways" through which natural enemies as well as pollinators can reach the various parts of a farm. This practice is particularly beneficial for pollinator-deprived landscapes.

Actions related to this practice

- 'Prioritizing Perennial Plants'
- 'Match Irrigation Technique to Climate, Topography, and Water Availability'
- See appendix section 2 for more details

Applicability

Parts of the system aren't profitable (or are costing the farmer money to farm) and there are pest issues even while using pesticides

% of farmland natural/semi-natural non-crop areas

Requires time to see benefits (3-5 years)

Requires species specific knowledge

Requires site specific planning

Increasing functional biodiversity & agroecological system services

Decreased single species yield

Increasing system resilience

PRACTICE

ADDING STONES AND BRANCHES TO THE LANDSCAPE

Description

Interspersing stones and branches amongst the orchard trees for habitats

This practice is fairly simple, adding stone and branches to the landscape (range of sizes from small to large) to provide habitat for functional biodiversity. Stones are a predominant component of many agrarian landscapes, and have been traditionally used to delimit field margins or mitigate the course of water, while preserving humidity in the soil. Cut branches as well as other (healthy) foliage from pruning or forestry works can be integrated into the landscape as well. Both stones and branches are freely available products that can easily enhance agroecosystem services. Cover crops, flower strips, and other living elements are a great host for insect biodiversity. On the other hand, stones and branches create the habitat for reptiles, beetles, and mammals, which interact with the agroecosystem modifying overall pathogen behaviour.

Actions related to this practice

- 'Mulching with Organic Material'
- 'Nutrient Analysis and Budgeting of Soil and Crop'
- 'See appendix sections 2 & 3 for more details'

Applicability

Stones and branches are available.

	Presence/Absence of stone/branch landscape elements
	Requires additional labor
	Increasing functional biodiversity & agroecological system services
	Improves water filtration

SOCIAL POINTS OF VIGILANCE

Regenerative farming practices inherently require a transformative change in the way a farm operates. Because of this, it's essential to think on the human level of what these changes practically mean. Additionally, it's important that the risks associated with each practice in terms of human/labor rights, social conditions, and conditions of unequal access are considered. In this table, we section, we examine these considerations more closely for each of the practices outlined in the document.

The essential practices that should be implemented in concert are:

ESSENTIAL PRACTICES	SOCIAL VIGILANCE POINTS TO FLAG
☑ **Avoid Bare Soil**	• See: Cover Crops as Green Manure • See: Mulching with Organic Material • See: Living Fences/Hedgerows/Windbreaks
☑ **Cover Crops as Green Manure**	• Food insecurity • Requires additional labor-Flag for labor risk countries • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining • Equitable / cheap access to this expertise • Access & safety to additional machinery
☑ **Minimize Soil Disturbance**	• Access & safety to additional machinery
☑ **Living Fences/Hedgerows/ Windbreaks**	• Social pressure from neighbors • Need cheap access to this expertise • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining
☑ **Mulching with Organic Material**	• Farmer income & end markets • Equitable / cheap access to this expertise • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining • Food insecurity • Access & safety to additional machinery
☑ **Plant and Field Maintenance for Pest and Disease Prevention**	• Equitable / cheap access to this expertise • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining
☑ **Match Irrigation Technique to Climate, Topography, and Water Availability**	• Farmer's income • Equitable / cheap access to this expertise • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining

ESSENTIAL PRACTICES	SOCIAL VIGILANCE POINTS TO FLAG
☑ **Nutrient Analysis and Budgeting of Soil and Crop**	• Farmer income & end markets • Equitable / cheap access to this expertise • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining • Access & safety to additional machinery
☑ **Prioritizing Perennial Plants**	• Farmer's income & end markets • Equitable / cheap access to this expertise • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining • Neighbor and peer pressure (Increased Pest Potential)
☑ **Increasing Crop Biodiversity**	• Economic viability • Neighbor and peer pressure (Increased Pest Potential)
☑ **Livestock Integration**	• Potential permitting barriers • Potential pressure from neighbors re: impacts of livestock (sounds/smells/crossing property lines) • Equitable access to expertise • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining
☑ **Intercropping with Other Tree Species**	-
☑ **Increasing Percent of Natural/ Semi-Natural Non-Crop Areas/ Habitats**	• Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining • Equitable / cheap access to this expertise • Neighbor and peer pressure (Increased Pest Potential)
☑ **Adding Stones and Branches to the Landscape**	• Neighbor and peer pressure (Increased Pest Potential) • Attention to : i) youth labor, ii) living wage, iii) gender wage gap, iv) work safety (fatal/ non-fatal accidents in the workplace), v) working hours, vi) collective bargaining

DETAILS ON CROP TYPE SPECIFIC IMPLEMENTATION

TREE FRUIT

HIGHEST CONFIDENCE PRACTICES	TIME SCALE	VARIABILITY
Which practices have the highest confidence of providing benefit to this crop type?	*What is the time scale for the expected benefits of the highest confidence practice?* Now 1 2 3 4 5 yrs	*How variable are the benefits of this practice between different climates and different crops within the typology?* Globally Aplicable / Varying factors
Cover Crops & Green Manure	*1 YEAR* Farmers can reap benefits of agroecosystem services (soil fertility, (SOM), weed suppression).	Applies with tree crops, in all climates.
Living Fences/ Hedgerows/Windbreaks	*1-5 YEARS* In about two years farmers will see benefits from the living fences/hedgerows - semi natural habitat starts to be created and agroecosystem services will start to be provided. The benefits can be fully realized in about five years. Mix annuals and perennials the first year for maximum benefits.	Depends on the size of the orchard, living fences are most effective if implemented every 20HA or so.
Minimize Soil Disturbance	*6 MONTHS-3 YEARS* Expected benefits: half a year to see measurable benefits (soil life, soil structure increase), could see fruit-related benefits by the second harvest season.	Applies with tree crops, in all climates.
Tree and Field Maintenance for Pest and Disease Prevention	*IMMEDIATE* The slowing of disease will be immediate and the beneficial effects will be ongoing.	Best practices are generally applicable: prevention, observation, intervention in the proper way -- specific practices may vary between climates and tree crops.
Increase Soil Organic Matter (SOM) (manure, compost, biofertilizers)	*2 YEARS* The improved soil nutrient should be visible in fruit-related benefits after the second harvest.	The specific best practice techniques for increasing soil organic matter may vary **depending on climate, topography, soil type, and site specific species interactions.**
Match Irrigation Technique to Climate, Topography, and Water Availability	*IMMEDIATE* After implementation of the appropriate irrigation technique, the use of less water and the increase of water availability will be ongoing.	Entirely dependent on local climate and water availability to selectselectg the appropriate technique for water management.

BUSH FRUIT

HIGHEST CONFIDENCE PRACTICES	TIME SCALE	VARIABILITY	
Which practices have the highest confidence of providing benefit to this crop type?	*What is the time scale for the expected benefits of the highest confidence practice?* Now 1 2 3 4 5 yrs	*How variable are the benefits of this practice between different climates and different crops within the typology?* Globally Aplicable / Varying factors	
Functionally Diverse Cover Crops to Supplement Nutrient Needs	*2 YEARS+* As long as synthetic pesticides are also reduced the increase in functional biodiversity will provide habitats for pollinators and natural predators of insect pests in about two years.		The type of cover crops needed varies based on the nutrient and growing conditions needed for each bush fruit type and should be matched accordingly.
Mulching with Organic Materials	*1YEAR* By the second year there will be benefits in increased soil organic matter with green mulching, and more immediate soil organic matter increases can be seen with other organic materials as mulch (such as straw).		All crops, all climates, mulch type and tradeoffs can vary (ex. wood mulch stays around for longer and does better with reducing weed pressure but also immobilizes nitrogen).
Tailoring Pest & Disease Management Based on Observation and Pest Presence	*IMMEDIATE-LONG TERM* The pest management plan should be tailored based on the needs of the farm through observation and adaptation. For example, if there is deer pressure on the farm, fences or hedgerows can be effective and the time scale will range from immediate -> five years. But generally, pest management will be an ongoing challenge, though increasing soil biodiversity and health over time should help to prevent high disease pressure.		The approach will depend on the types of pest (animal) pressures, the stage of growth of the fruit. Requires iteration based on observation & reaction.
Intercropping with Multiple Species of Leguminous Trees & Shrubs for Nitrogen Fixation	*2-3 YEARS* The breakdown of nitrogenous leaf litter is slow and it will take years before there's enough leaf litter for the plants to have an impact on the N content of the soil.		Different bush fruit have different tolerance for shade different nutrient and soil chemistry requirements this is something to consider when designing the system.

GROUND FRUIT

HIGHEST CONFIDENCE PRACTICES	TIME SCALE	VARIABILITY
Which practices have the highest confidence of providing benefit to this crop type?	*What is the time scale for the expected benefits of the highest confidence practice?* Now 1 2 3 4 5 yrs	*How variable are the benefits of this practice between different climates and different crops within the typology?* Globally Aplicable / Varying factors
Cover Crops as Green Manure and Crop Rotation	*1YEAR* Farmers can reap benefits agroecosystem services (soil fertility, soil life, weed suppression).	The variety of plants chosen as cover crop will change depending on location.
Living Fences/ Hedgerows/Windbreaks	*1-5 YEARS* In about two years farmers will see benefits from the living fences/hedgerows - semi natural habitat starts to be created and agroecosystem services (increased pollinator populations, increased pest predators populations, increased soil biodiversity) will start to be provided. The benefits will be fully realized in about five years. Mix annuals and perennials the first year for maximum benefits.	Depending on the size of the farm these barriers may not be just effective on the outside of the farm but also between crop planting.
Adding Soil Organic Matter (SOM) (mulching, composting, or biofertilizers)	*2 YEARS* The slowing of disease will be immediate and the beneficial effects will be ongoing.	The specific best practice techniques for increasing soil organic matter vary depending on climate, topography, soil type, and site specific species interactions.
Pest Management by Observation and Application of Bio-Fungicide/Pesticide	*IMMEDIATE* Biofungicide application when necessary, could see results (lack of pests) in about 2 months based on application rates.	Depends a lot on the neighbors' activities: their pesticide use and other activities will determine what pests are present in what magnitude on the farm. The application rates will likely need to be based on rain conditions.
Minimize Soil Disturbance	*6 MONTHS-3 YEARS* Expected benefits: half a year to see measurable benefits (SOM increase, soil structure increase), could see fruit-related benefits by the second harvest season.	Applies with crops, in all climates.
Match Irrigation Technique to Climate, Topography, and Water Availability	*IMMEDIATE* After implementation of the appropriate irrigation technique, the use of less water and the increase of water availability will be ongoing.	Entirely dependent on local climate and water availability to select the appropriate technique for water management.

PLAN DEVELOPMENT

The first step in the transition to regenerative agriculture is to create a transition plan. The creation of these plans should include essential stakeholders: a farmer, farm workers, and local agronomists and/or NGOs. The plan should wait to reduce inputs (such as synthetic pesticide and fertilizers) for at least six months to retain yield. In addition, plans should include a consideration of where any funding necessary for the initial and sustained costs of running a more labor intensive regenerative farming operation will come from. Local, expert knowledge is a prerequisite for implementing almost all of the essential practices. The plan should include:

- **How each essential practice will be implemented:**

- [x] **Avoid Bare Soil**
  - Introduce cover crops and mulch
- [x] **Cover Crops as Green Manure**
  - Determine a planting schedule for which crops will be planted where and when. This will require expert knowledge of companion planting and local plant varieties that work best for the climate and crop type.
- [x] **Minimize Soil Disturbance**
  - Determine a scheme for phasing out ploughing/ tilling. This may require additional machinery.
- [x] **Living Fences/Hedgerows/Windbreaks**
  - Map out where windbreaks would be most useful and devise a planting plan for including them on the farm. This will require local expert knowledge on native plant combinations for best results for increasing pollinator and pest predator populations.

Mulching with Organic Material

- [x] Source or grow mulch (i.e. straw).

Plant and Field Maintenance for Pest and Disease Prevention

- [x] May require education on best practices for best practice, determine the best way to schedule this for the farm. This may require additional labor.

Match Irrigation Technique to Climate, Topography, and Water Availability

- [x] Expert knowledge of water management systems will be required to map and implement water systems.

Nutrient Analysis and Budgeting of Soil and Crop

- [x] Initializing a nutrient testing regime for soil and fruit nutrient content.

Prioritizing Perennial Plants

- [x] Determine where perennial planting can be incorporated into cropping, cover cropping, intercropping, and hedgerows.

Increasing Crop Biodiversity

- [x] Determine whether there are additional varieties that can be grown to increase crop biodiversity.

- **A phased timeline for when each practice will be implemented**

- **Which of the additional practices will be implemented**

Livestock Integration

- [ ] Determine which species will be integrated, whether they'll visit the farm or be permanently situated there.

Intercropping with Other Tree Species

- [ ] Determine whether the crop tolerates shade and whether there are compatible and useful trees to plant within the cropping area.

Increasing Percent of Natural/Semi-Natural Non-Crop Areas/Habitats

- [ ] Determine whether there is part of the farmland that is unproductive and should be transitioned back into natural landscape.

Adding Stones and Branches to the Landscape

- [ ] Determine whether these landscape additions would interfere with farm machinery and if they're available for use.

When building a plan, use the framework below to determine whether the farm is installing measurable practices in line with the essential regenerative agricultural practices for fruit.

OPTIONS FOR MONITORING ESSENTIAL PRACTICES

Essential Practices	Questions	Metrics
Building a plan	Is there a plan being developed with the farmer and an agronomist to help assist the regenerative transition?	Y/N
Cover cropping/ Green Manure	What % of the field is covered in vegetation?	%
	How many plant species are sown?	# plant species
	Are there secondary crops?	Y/N
	If so, how many secondary crops	# secondary crops
Living Fences/ Hedgerows/Windbreaks	Are there plans to plant diverse hedgerows/living fences?	Y/N
	How many plant species will be included in the hedgerows/living fences?	# species
Minimize Soil Disturbance	Is there tillage/ploughing on the farm?	Y/N
	If so, how often?	# passes
	If so, what depth of tillage?	# cm
Tree and Field Maintenance for Pest and Disease Prevention (*applicable for trees and bush fruit)	Is there regular maintenance/pruning of trees/shrubs?*	Y/N
	Are infected plant parts disposed of in a way that prevents them from infecting other plants on the farm?*	Y/N
	Are synthetic pesticides in use?	Y/N
	Is pesticide used to treat specific problems (vs. regular i.e. weekly spraying)	Y/N
Increase Soil Organic Matter (SOM) (manure, compost, biofertilizers)	Performing regular soil nutrient analysis?	Y/N
	Are the inputs of fertilizer being matched to the results of the nutrient testing?	Y/N
	Mulching with organic matter?	Y/N
Water Management	Doing water quality testing?	Y/N
	Using water sensors?	Y/N
	Using a decision support tool for water management?	Y/N
Livestock Grazing (After Harvest)	Are livestock integrated in the farm land?	Y/N
	If yes, how many species?	# species
	Are the livestock grazing after harvest?	Y/N
	How frequently?	# days per yr
Additional Cost	Does this plan require additional labor?	Y/N
	Does this plan require additional machinery?	Y/N
	Does this plan require additional cost?	Y/N

APPENDIX

METHODOLOGY

In order to provide broadly applicable advice on implementing regenerative agricultural practices for fruit, we have organized the recommended practices into six action categories:

1. **Cover and Intercropping:** determine what complementary plants to seed within and around the cropping systems.
2. **Landscape Elements/Ecological Infrastructure:** determining what design elements will provide functional biodiversity and other benefits to the cropping system at the landscape scale.
3. **Soil Management:** determining what practices to select in order to protect soil structure and increase soil health.
4. **Phytosanitary/Pest Management:** determining what actions to take to prevent pest and disease outbreaks, build resilience to pests and disease within the cropping system as well as mitigating them when they do occur (reducing reliance on synthetic pesticides).
5. **Nutrient Management:** determining how to adequately provide sufficient nutrients to the cropping system while moving away from synthetic inputs.
6. **Livestock Integration:** determining how to best integrate animals into a cropping system to provide benefits to soil health, and pest and disease reduction.

We first completed desk research to determine what evidence could be found in academic sources supporting practices in each of these six action categories for three different fruit typologies (tree fruit, bush fruit, and ground fruit). Once we had exhausted the academic research available, we integrated relevant literature from the regenerative agricultural community. Therefore, we created a framework for each of the three crop types covering the six action categories above and describing the respective benefits, compromises, considerations, and complementary actions for possible regenerative practices. We engaged three regenerative agriculture farmers and agronomists to review and critique these frameworks for accuracy.

After we received input from expert practitioners on our framework of academic evidence, we hosted workshops with these experts to identify which actions had the most consistent benefits across each crop typology and action category. For each of these high-confidence practices, we have noted how long it takes to fully realize the potential benefits as well as any variation of those benefits in a variety of contexts.

1 COVER AND INTERCROPPING

Actions that are related to this category: Avoiding Bare Soil, Cover Crops as Green Manure, Mulching with Organic Material, Intercropping with Other Tree Species, Intercropping with Other Tree Species, Prioritizing Perennial Plants, Increase Crop Biodiversit.

BENEFITS

Increased soil quality and nutrient cycling
- Increase soil's organic matter: Higher soil C and N[1–5]
- Higher microbial abundance, activity, and diversity[3,6,7]
- Decreased runoff and erosion[5]
- Reduced leaching of nitrogen[8]

Increased beneficial soil microfauna populations
- Increased C and N pools favour beneficial rather than herbivory nematodes, keeping pathogens in control[1]

Weed suppression
- Suppression of spontaneous vegetation, reducing weed pressure to tree crops, due to allelopathic capability of appropriate cover crop mixtures[9,10]

Pest control
- Habitat provision for natural pest enemies[10–14]

Enhanced pollination
- Habitat provision for pollinators diversity[11,15,16]

Increased yield
- When cover cropping is properly planned, higher yield is obtained through either increase in fruit set/size and/or increased photosynthetic activity[15,17,19]

Protection against extreme weather events
- Higher agroecosystem resilience and faster productive recovery compared to monocultures[20]

TRADE-OFFS/COMPROMISES

Potential habitat for pests (e.g. voles)[4]

Potential nutrient imbalances
- Competition with trees for soil resources[4]
- Lower nutrient content within plants or soil (but not with annual crops and minimum tillage)[2,19]

Seed cost & Efficacy
- Costs associated with purchasing seeds and difficulty of establishment (higher e.g. with wild flowers that prefer nutrient-poor environments, and/or under the shade of tree in agroforestry systems)[10]
- This might not always be justified in case of little gains[1]

Need for crop & site-specific design
- Highly variable effects depending on species selection and environmental factors, not so much in-depth location-specific research available[11]

Potential lower single-species yield
- The yield of individual species in agroforestry systems is lower than in monocultures[21]

COMPLEMENTARY PRACTICES

Actions 1, 3, & 4 see maximum benefit when combined with minimum soil disturbance
- Yield, SOC, N and P can be maximized by a combination of annual alley crops, minimum tillage and organic fertilization[2]
- Greater mycorrhizal colonization when combined with less intensive tillage[7]

Actions 1, 3, and 4 see maximum benefit when the cover crop mixture includes legumes and other functional groups
- *When using legumes as a cover crop, arbuscular mycorrhizal fungi (AMF) colonization can withstand some tillage[7]
- **Using legumes as a cover crop induces larges SOC increase than when using grass species[5]
- Use of a mixture of cover crops, including both legumes and non-legumes, like cereals, increase agroecosystem services provided like weed suppression, nitrogen retention, and productivity[18,22,23]

The risk of lowering yield is minimized by additionally using biofertilization techniques
- Yield increase through AMF combined with microorganisms application (P solubilizers and N

2 LANDSCAPE ELEMENTS/ECOLOGICAL INFRASTRUCTURE

Actions that are related to this category: Avoiding Bare Soil, Living Fences/Hedgerows/Windbreaks, Intercropping with Other Tree Species, Increasing Percent of Natural/Semi-Natural Non-Crop Areas/Habitats, Adding Stones to the Landscape, Prioritizing Perennial Plants.

BENEFITS

Pest control

- **Habitat provision for functional elements of biodiversity (beneficial arthropods)[1,2,16,25–27]**
- **Increase in insectivorous birds abundance)[1,2,3,28]**

Landscape-scale biodiversity conservation

- **Linking forests and other natural habitats, acting against habitat fragmentation[29,30]**

Wind mitigation[29]

Enhanced pollination

- **Habitat provision for pollinators diversity, with positive effects on yield[30,31]**

TRADE-OFFS/COMPROMISES

Pest habitat provision[1,2]

- **A greater % of semi-natural habitats can also serve as a host for crop pest populations[25,28]**

Need for site-specific design[1,2]

- **Highly variable effects depending on species selection and environmental factors, not so much in-depth location-specific research available[27]**

3 SOIL MANAGEMENT

Actions that are related to this category: Avoiding Bare Soil, Cover Crops as Green Manure, Minimize Soil Disturbance, Mulching with Organic Material, Adding Stones to the Landscape.

CONSIDERATIONS

- The minimum soil disturbance practice along with the application of organic mulch and soil amendments like compost and biochar, can improve soil structure and health, aid in weed and disease control, and over time cut on cost for inputs and increase yield.
- Precautions should be taken against potentially undesirable side-effects (e.g. increase in soil pH, lower spring soil temperatures) and field research is needed for best application rates and the selection of organic materials employed.
- Something to consider is that in some countries legal constraints may exist on the use of byproducts/waste also for biochar, which was only very recently allowed to be used in organic farming.[32]

BENEFITS

Enhanced soil microbial communities[1,2]

- Organic mulching systems support soil bacterial and (most of all) fungi communities which are generally associated to positive effects[7,33]

Pest and disease controls[3]

- Habitat provision for natural pest enemies (organic mulch) and fungal disease control (biochar for ground fruit production)[33–36]

Weed control[2]

- Weed suppression while buffering soil temperatures and releasing nutrients[37–39]

Increased plant yield[1,2]

- For example by enhancing root growth, nutrient availability and uptake, water storage and use efficiency (even though more research is needed to determine best application practices)[40–43]

Improved soil structure[1,2]

- Enhanced soil structure and water/nutrient retention capacity, decreasing irrigation needs[44]

Reduced run-off and sediment load[1]

- Soil physical properties safeguarded by minimum soil disturbance practices and contour planting[45,46]

Costs reduction[1]
- Labour and fuel savings under reduced tillage[47]

TRADE-OFFS/COMPROMISES

Lower soil temperatures[2]
- Under organic mulch (might be an advantage in hot climates)[48]

Need for organic mulch selection and testing[2,3]
- Organic materials can be costly, not easily available, or difficult to handle[48,49]
- On the long run, soil water repellency effects might be induced to some extents[50]
- Disease-promoting organisms and/or crop pests might be hosted by decomposing organic material[51]

Need proper application to avoid undesirable effect[3]
- Trend of increasing soil pH which might be problematic for specific crop types[41]
- Decreasing soil N if biochar not activated with nutrients[52]
- Improvements might be lower in already fertile soils[53]

COMPLEMENTARY PRACTICES

Use of cover crops / Green manure and minimum soil disturbance[1,2]
- Use of a mixture of cover / green manure species combined with minimum, restricted to shallow (<10 cm) tillage, applied in strips among tree-rows can obtain the maximum benefit in terms of both practices (minimum tillage and cover crops application).

4 PHYTOSANITARY/PEST MANAGEMENT

Actions that are related to this category: Plant and Field Maintenance for Pest and Disease Prevention (E)

CONSIDERATIONS

- A holistic pest management approach should be always considered, starting from prevention/ precautionary measures, pest and diseases inspection before any interventional measures are taken.
- Most of the benefits of pest management practices will be found as benefits of practices listed in other parts of the framework. Biochar, syntropic agroforestry, intercropping and targeted interventions like falconry and entomovectoring can be effective when dealing with specific pests.

ACTIONS

1. Priority action: Prevention of pests and diseases from becoming a problem by implementing integrated/ holistic approach for general best farming practices (i.e. sanitization of tools and inputs, correct pruning, irrigation etc)
2. Increasing functional biodiversity: Enhancement of biological control agents i) beneficial arthropod fauna ii)s flora/host of beneficials
3. More specific techniques of pest management are possible[3.1] Biological Control approach/use of microbial agents (i.e. Bauvaria Bassiana, trichoderma, Bacillus subtilis),[3.2] entomovectoring** (targeted pest control via pollinators),[3.3] falconry* (for small bird pest management))

BENEFITS

Reduced small bird pests[3.3]
- Reduced crop loss[54]
- Reduced e-coli risk in ground crops[55]

TRADE-OFFS/COMPROMISES

Cannot be paired with chickens[3.3]
- Falcons/birds of prey will not only go after pest birds but also chickens/eggs[55]

COMPLEMENTARY PRACTICES

Support health of pollinator communities[1,2,3]
- Entomovectoring works best when there is a healthy pollinator community, particularly through managed vegetation habitat for pollinators[56]

5 NUTRIENT MANAGEMENT

Actions that are related to this category: Cover Crops as Green Manure, Mulching with Organic Material, Intercropping with Other Tree Species, Nutrient Analysis and Budgeting of Soil and Crop, Increase Crop Biodiversity.

CONSIDERATIONS

- Application of biofertilizers and timing nutrient management according to the physiological needs of the plant, can enhance crop growth, nutrient use efficiency, stress tolerance and disease resistance, potentially boosting yield and organoleptic characteristics
- Moving from regularly applied synthetic nutrients toward organic inputs takes time and can be done most efficiently by keeping track of the nutrients in the soil through simple testing and analysis.

BENEFITS

Plant physiology
- Enhanced crop growth[57–64] and nutrient use-efficiency[24,62]

Stress tolerance
- Reduced negative effects of abiotic stresses (e.g. frost, drought, salinity, etc.)[62–66]

Disease control
- Systemic acquired resistance to common pathogens[62,67,68]

Increased Yield
- Thanks to nutrition-related benefits and disease/stress pressure reduction[24,57,59,61,69–71]

Enhanced nutrient content
- Increased nutrient levels in the fruit and/or crop quality parameters[57,58,60,61,71]

Potential cost reduction
- In case of self-production, which also increases farm self-sufficiency[70,71]
- Synchronize nutrient inputs with crop needs[2,72]

Increased effectiveness of regenerative practices
- Sap analysis can synchronize the timing of any other management intervention, enhancing the impact of bio-intensive practices[71]

TRADE-OFFS/COMPROMISES

Continuous adjustments needed
- A nutrition program fine-tuned to the plant physiology requires continuous monitoring and nutrition adjustments to match crop needs[71]

Effectiveness variability:
- The complexity of biological systems, environmental variables and, in case of self-production, difficulties in process standardization, result in highly variable plant and yield responses[24,63]

Challenges large-scale self-production
- That can be time and resource-consuming, even though new technologies are becoming available[70]

Sophisticated approach
- Some detailed measurements required of losses including leaching, denitrification, ammonia volatilization etc[72]

COMPLEMENTARY PRACTICES

1. Microbiology-friendly management practices (e.g. cover cropping and minimum soil disturbance)
2. Preserving the soil microbiome lowers the need of biofertilizer consumption[70] (Be aware of potential drawback: Drip system increased maintenance. In case of fertirrigation with products containing coarse plant/animal particles (does not apply for microbial-only formulations)[73])
3. Cover cropping/Green mulch using cover crops as green mulch provides additional nutrients into the soil and over time helps build soil organic matter. These practices help build the overall nutrient content and nutrient potential of the soil.

6 WATER MANAGEMENT

Actions that are related to this category: Match Irrigation Technique to Climate, Topography, and Water Availability.

CONSIDERATIONS

- Simple irrigation management tools are widely available requiring only basic competences by farmers in terms of their use
- Capturing run-off and redistributing water through water harvesting technologies and cultivation patterns has positive effects on soil conservation, water availability, and in turn plant growth and production
- Interventions need to be tailored based on agroecosystem needs and landscape physiology, considering scale and return on investment

ACTIONS

- Implementation of water-harvesting technologies, both soil storage (including planting pits, ridge-and-furrow, stone bunds, terraces, etc.) and reservoir storage (ponds, small check dams, underground water tanks) and cultivation techniques (keyline cultivation pattern and Yeomans plow)

BENEFITS

Enhanced water availability

- Capturing surplus run-off increases the water potential of the agroecosystem[1,2,74]
- Rehydration of the overall soil profile[3,75]

Enhanced yield

- Especially in low rainfall areas[76,77]

Sediment retention and reduced erosion

- Decreased runoff preserve farm's soil while decreasing sedimentation and desilting costs[77–79]

TRADE-OFFS/COMPROMISES

Implementation costs

- Particularly in regions with lower marginal yield gains (where major limiting factors are others rather than water availability) and in case of bigger interventions[76]

Need for site-specific design and maintenance

- Effectiveness needs fine-tuning of water interventions to the local context[77]

COMPLEMENTARY PRACTICES

Highest yield opportunities given by a combination of water harvesting and intercropping/cover cropping[77]

Cover crops/mulching and minimum soil disturbance

- Use of a mixture of cover crops and mulching combined with minimised tillage, reduce evapotranspiration (important for arid areas) and retain water for tree crops during fruit ripening season when is most necessary

7 LIVESTOCK INTEGRATION

Actions that are related to this category: Livestock Grazing.

CONSIDERATIONS

- Integrating animals in the system has multiple benefits, such as optimizing resource and land use, controlling pest and weeds, building soil fertility, and constructing alternative revenue streams; all of this while guaranteeing superior animal welfare conditions
- Animal integration implies extra costs in terms of equipment, labour and know-how, and logistics. There must be a very careful consideration of the species and breed selected, and the timing of animal interventions, in relation to the particular crop type

BENEFITS

Weed control
- Through the scratching/pecking/grazing behaviour of animals[80–84]

Pest control
- By breaking the pest cycle eating fruit residuals[84–86]

Soil fertility
- Enhanced soil health and nutrient cycling[81,86,87]

Resource optimization[1,2]
- Effective conversion of farm wastes in crop inputs, increasing the efficiency of land use[81,87]

Additional revenue streams
- Diversification of income opportunities with increased farm resilience[83,88]

Animal welfare
- Animals can manifest their natural behaviours, and are sheltered by sun, wind, and climatic extremes[88]

TRADE-OFFS/COMPROMISES

Need for crop-specific timing
- Animal management must be fine-tuned to the crop's physiological stage and agronomical requirements[80]

Extra costs
- In terms of equipment needed (e.g. mobile structures, fencing, tree protections), labour, and know-how[83]

Effectiveness depends on animal species and management
- Variable results highlight the need for appropriate selection of factors such as species, breed and density[82,84]

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