Almonds

eit Food

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Contents

1. An introduction to regenerative almond production

This section is designed to help farmers implement regenerative practices on an almond orchard. It will explore the practical planning, design and implementation of a regenerative system, including examples and learnings from existing regenerative orchards in the region. But first, why does regenerative agriculture matter to almond farmers?

In many Mediterranean countries, the soil that feeds our farms is degrading dramatically. Frequent ploughing disturbs the soil and enables wind and water to erode the precious topsoil; meanwhile, erosion, compaction and nutrient poverty all reduce the soil's ability to support crops. We're already seeing the effects of this phenomenon through desertification that has left many areas and farms unable to sustain themselves.

Fortunately, there is a solution. Regenerative farming can reduce erosion, improve CO2 uptake, improve the structure of the soil, nurture organic matter, promote biodiversity and reduce energy use. Not only that, but regenerative farming enables farmers to command a fair price for their crop, guaranteeing their land and business for years to come.

In the following chapters we will discuss how to design, plan, and manage a regenerative dryland almond field. We will work from two different starting points: designing and planning a brand new almond orchard, and upgrading a conventional/certified organic plot to a regenerative one.

(Most of the expertise in this section is obtained from farmers working in a dryland Mediterranean climate, often in higher-altitude areas. For more information on some of these farms, see the 'Case Studies' section of this manual.)

Almond cultivation today

As farmers look for alternative crops to beat increasingly difficult farming conditions, the supply of almonds is growing. Almond trees thrive on marginalized land, and they are becoming more and more common across Mediterranean climates (including the US, Spain, Australia and Chile). The almond is already the most commercially significant tree nut in terms in the European Mediterranean, and Spain is the third-largest producer in the world, with 4% of total harvest volume, and the largest national area of almond cultivation (650.000 ha). With smaller farms, Italy struggles to keep pace with the intensive competition of industrial cultivation.

Most of the world's almond orchards are managed conventionally: they are tilled/ploughed more than 4 times a year (downhill), sprayed with herbicides and pesticides, irrigated heavily (mainly in California) and have no natural hedges or zones to support wildlife and pollinators. This type of management results in high levels of erosion, the loss of the fertile layer of topsoil, and a reduction in soil life and wildlife like rabbits, foxes, insects (such as bees and ladybugs). Because they are planted for the long-term, almond orchards have the potential to become a long-term home for wild pollinators – but too often, they remain a hostile environment.

In southern Spain, over 50% of almond orchards are organic – partly because the climate makes it difficult for pests to prosper, reducing the demand for pesticides. Nevertheless, organic practices alone (including natural pesticides) are not enough to improve soils, water, and biodiversity.

"'Going organic' has not been sustainable - just more of the same. Had we understood the different mindset needed to implement organic and regenerative farming, we would've saved ourselves many avoidable mistakes.".

- Farmer from Malaga -

Almond cultivation: Why go regenerative?

Recent studies have proven that introducing regenerative practices to your farm can increase the productivity of the field, as well as boost soil fertility and water levels. In addition, regenerative practices like vegetation cover, compost and swales can help almond orchards retain much more CO2: one hectare of regenerative almonds can have an annual retention of 15,2 t C/ha/per year.[1]

By replenishing the ecosystem, regenerative practices enable the farmer to become a steward of the land, securing a healthy, abundant crop for generations to come.

1. *Carbon emissions in organic rainfed orchards* (2020); by Martin-Gorriz, B., Maestre-Valero, J. F., Almagro, M., Boix-Fayos, C., & Martínez-Mena, M. Scientia Horticulturae, 261, 108978

”We see ourselves as a sustainable project that works on regenerating ecosystems while at the same time producing high quality products. We do not use chemical products, we take care of soil fertility and make sure our crops have all the properties they are supposed to have. By having a balanced ecosystem we can control pests in a natural way. For example, lady bugs, beetles and lacewings help us to control aphids in almonds”.[2]

- Source : Cortijo El Puerto -

Research has shown that the market for almonds and their derivative products is growing in Europe and beyond. Commonly sold as whole almonds, almond pieces, almond milk or almond paste, they are most-used in bakery, confectionary, dairy and sweet and savoury snacks. And demand shows no sign of slowing: in 2019, more than 5000 new almond-related products were introduced in Europe.

In the last few years, the price differences between organic and conventional almonds has also grown. For traders, in-shell regenerative, organic almond prices fluctuate between 2-3 EUR/kg[3] while conventional prices lie around 1.50EUR/kg. According to AlVelAl, out-of-shell organic prices for farmers fluctuate between 7-9 EUR/kg[4] with conventional prices around 3.50EUR/kg. One regenerative cooperative in southern Spain reports a 5/10% price premium for farmers selling regenerative organic (Alfonso Chico de Guzman - Farmer).

2. https://www.cortijoelpuerto.com/cortijo-el-puerto-pionera-espana-obtiene-certificado-ecologico-cultivo-almendro-en-seto/

3. https://www.fdbusiness.com/almonds-ranked-the-number-1-nut-in-new-product-introductions-for-fifth-consecutive-year/

4. www.alvelal.es

General principles of regenerative agriculture




Understanding your context	Improving soil quality and health	Improving water management	Biodiversity	Holistic decision making
There is no 'one size fits all'. Consider your own specific land, soil, climate, crops etc.	Minimum tilling (to minimize soil disturbance and erosion by wind and rain)	Use of swales (contour trenches for water retention and infiltration)	Intercropping	Take the entire ecological system into account when planning and making decisions
	Vegetation strips and ground cover (to reduce erosion and evaporation and increase infiltration)	Use of ponds (for water harvesting and biodiversity)	Integrate plants and animals	Balance economic, social and environmental considerations
	Compost (to increase soil fertility through nutrients, micro-organisms and oil organic matter content)	Keyline or contour lines (to slow down run-off)	Crop rotation	
	Plant more perennials and other plants with vigorous root systems		Support natural pest management	
			Diversify the farm	
			Reforest and restore natural corridors	

2. Planning and design: Where to start?

What is your context? When starting from scratch, there are many regenerative practices that you can incorporate in your almond orchard design, planting the trees in such a way as to prevent erosion and increase water availability. In this chapter, we will explore the various factors you'll need to keep in mind when planting a regenerative almond orchard. We will look at examples of existing regenerative orchards and discuss different designs, tree varieties and rootstocks.

Some initial questions to ask yourself:

- Is your almond orchard on a hillside or on a flat area?
- What is the altitude of your farm?
- What is your water availability?
- How is your soil doing (pH, organic matter, nutrients, etc.)?

Dry land, <500mm rain a year, high altitude +800m, semi-flat. Source: AlVelAl

Dryland, <300mm rain a year, high altitude +800m, hillySource: AlVelAl

"If a farmer asks, 'Which tractor should I buy? What machinery?' - my advice is to invest that same money into improving the soil instead (compost, no till, intercropping). Rent the machinery instead, at least at the beginning"

-Matteo Mazzola, EIT agronomist Italy-

There are several ways of designing your orchard that can help increase soil fertility, biodiversity and water uptake. You'll need to consider these practices before planting the orchard. For example, one way of increasing biodiversity is to intercrop the almonds with another tree species (like olive) or to add hedges and borders to your initial design.

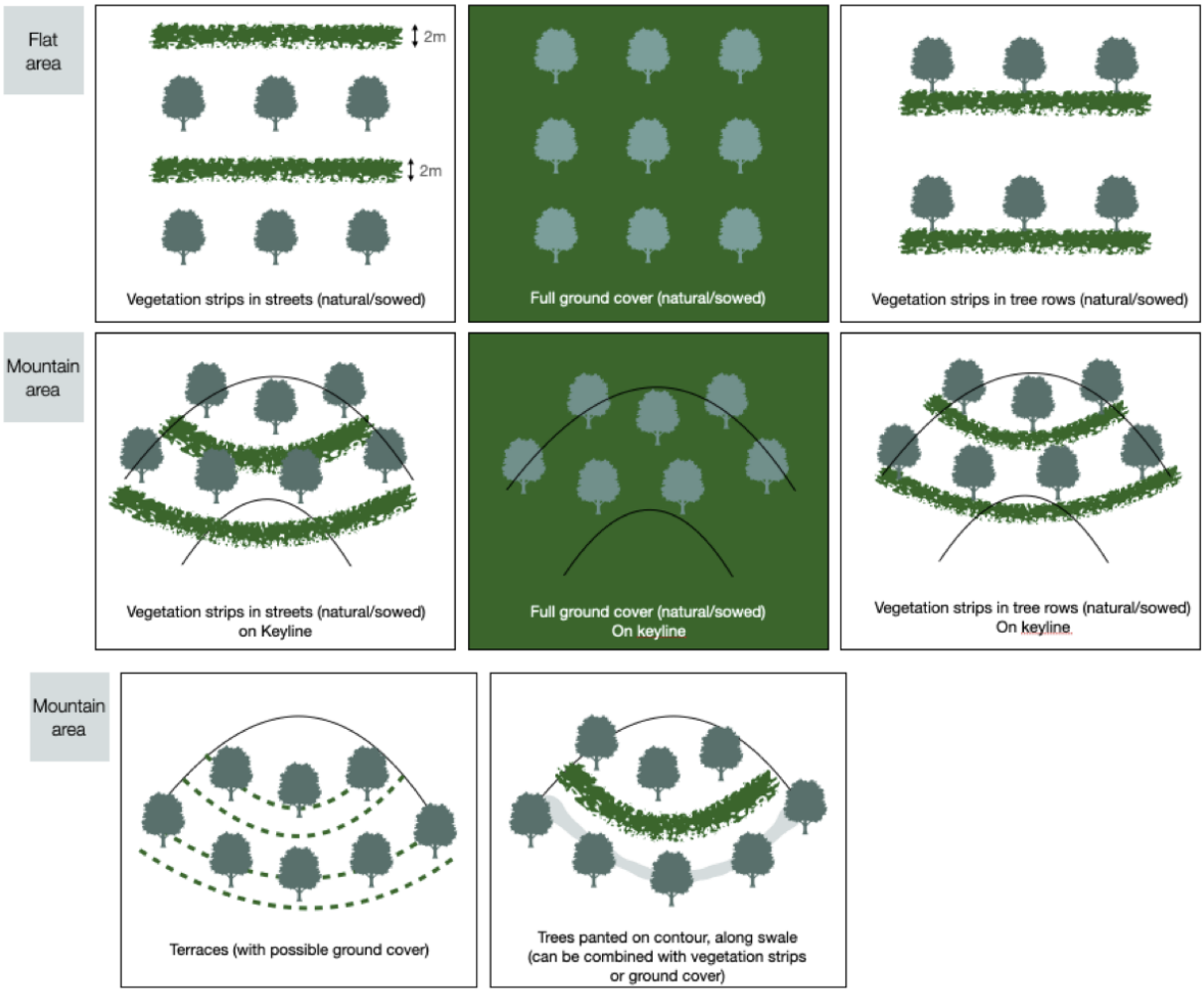
Spacing

The most commonly used tree spacing is 7x7m (200 trees per ha) with a wider spacing of 8x8 on very poor soils, or where there is little rainfall. The figure below shows different ways of integrating regenerative practices on flat and mountainous plots. The difference between mountainous areas and flat areas is that mountainous areas suffer from greater erosion, so improved water management practices can be especially beneficial. In hilly dryland areas, your design should take the following practices into account:

1. Use contour planting and tilling to prevent erosion
2. Use ground cover or vegetation strips on contour to prevent erosion and soil loss
3. Use swales, keyline, sediment traps and ponds to help retain rainwater

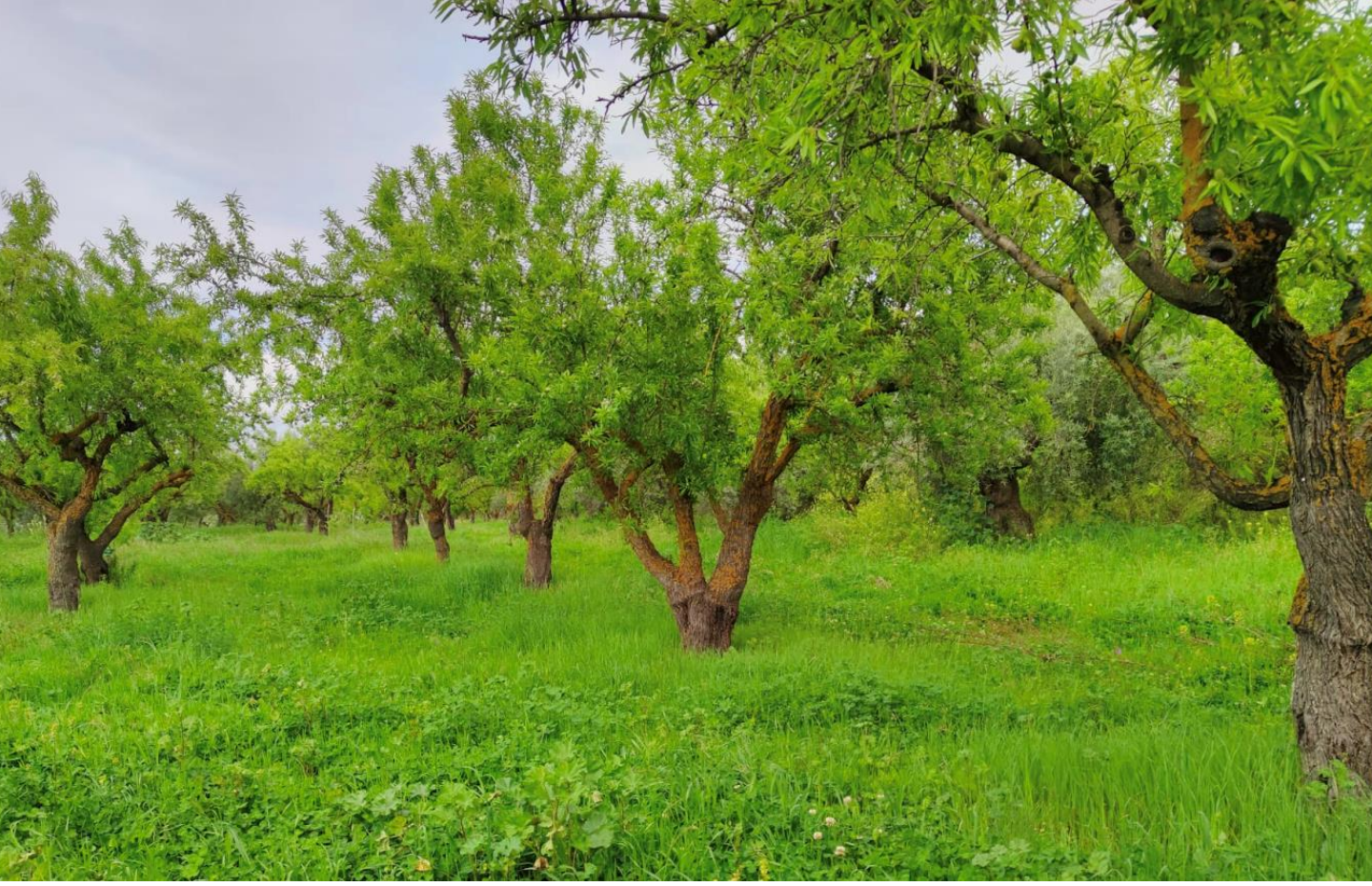
In flat orchards, erosion will not be a problem, but cover crops or vegetation strips can still greatly improve the soil quality.

We'll look at all these practices in more detail in the following section.



2.1 Almond varieties

Almonds adapt well to different conditions, from high and low temperatures to droughts and low-nutrient soil. In the Spanish Mediterranean, water availability is the main factor limiting growth. Almonds require a minimum of 250mm/year to survive and preferably more; they also need a minimum of 250 hours at temperatures lower than 7 degrees in winter to allow for dormancy. But at the same time, production is reduced when the flowering season is wet and cold – so almond trees tend to do best in Mediterranean climates with cold winters and long, warm summers.



When planting a regenerative almond orchard, it is important to consider the varieties available. Different types of soils and weather suit different types of trees. Before planting, check the rootstock that is used as the basis of the tree, as this will have a big impact on the tree's life cycle.

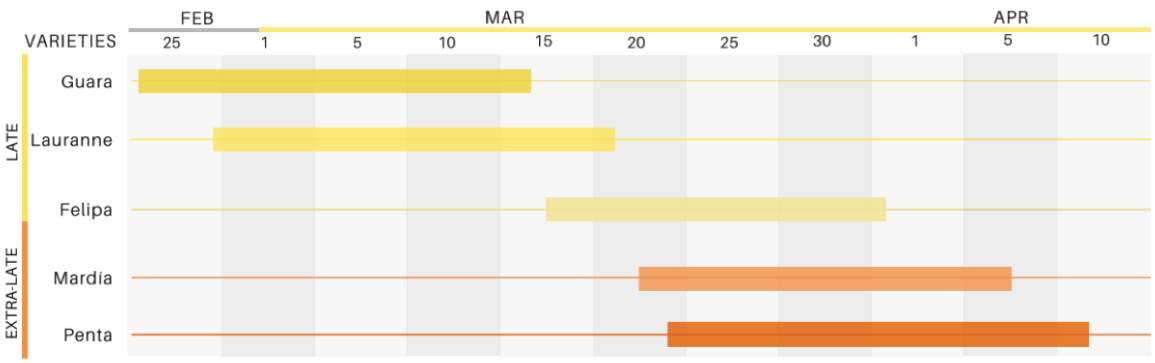
There are 3 types of rootstocks: 1) Bitter almonds 2) Garrigues and 3) Hybrids.

1. Bitter almonds are relatively risky, but they are more vigorous and tolerate drought better. One of the challenges of this rootstock is that it needs to be grafted properly – otherwise, you risk harvesting a high percentage of bitter almonds (which can result in fewer buyers). Furthermore, it can be difficult to find nurseries who sell bitter almonds because many are not allowed to stock them.

2 Garrigues and Don Carlo are good for dryland: similar to the bitter almond rootstock, but a safer option.

3 Hybrids (almond x peach) are made for irrigated lands and humid areas. They supposedly grow faster and yield earlier, but they also have a shorter life span. The names of some of these hybrids are Felinem, Garnem and Monegro.

Once you've chosen a rootstock, you can choose the variety that you'll graft on the rootstock. Your choice will depend partly on the time the almond blooms: the later the bloom, the more easily you can grow it in higher altitudes with later frost dates. The figure below shows the blooming of some varieties:



Blooming times of different almond varieties

Summary of the key considerations:

1. What are the contextual factors on my farm?
2. What objectives do I have for my farm?
3. Which rootstock is best suited to my context?
4. Which varieties fit my farm? (Investigate what works on farms in your area)

These are some of the varieties used around the Mediterranean:

Variety	Soil/ Characteristics	Challenges/risks	Production
Guara	Poor. Self-fertilization. It has been the most-planted almond cultivar in Spain.	Sensitive to ochre spots (fungal foliar disease). Branches are very soft and must be tied together.	Late flowering at the end of March. Medium but stable production. Not adapted to conditions with too much humidity. Kernel weighs 1-1.2 g, and its shell is hard. Harvest at the end of September.
Lauranne	Dry, permeable and aerated. Self-fertile. Orig. French, cross between Ferragnes and Tuono.	Lauranne has all the advantages of Guara. Resistant to diseases.	Late bloom in March. Regular production. Kernel weighs 1.3 g and has a semi-hard shell.
Felipa	Dry and calcareous. Self-fertile. Orig. Italian. Late bloom.	Needs more water than others, mixed results on different farms.	Flowers after 10th of March Harvests early in September. High production. Small almond size.
Mardia	Self-fertile. Orig. Spain, comes from Felisia and Bertina cross Drought tolerant.	Low disease rate.	Extra late bloom (middle to end of March). Almonds relatively small. Kernel weighs 1.2g, hard shell.
Antoiñeta	Good soil. Irrigated valley areas.	Difficult to prune because it tends to grow down. No special pest problems.	High harvest but very unstable. Size of almond a bit smaller than Guara.

2.2 Pests and diseases

Part of managing an almond orchard is dealing with insects - good and bad. As you'll know, pests can damage the roots, leaves or fruits of the tree. In conventional agriculture, this problem is tackled with toxic pesticides which also kill beneficial insects and other animals, resulting in air/water pollution and reduced wildlife.

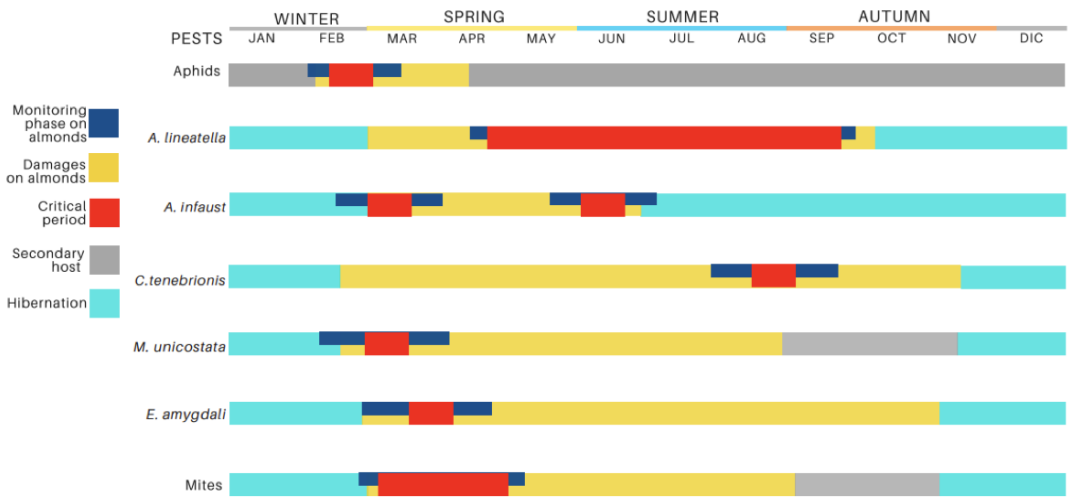
In regenerative agriculture, we manage pests in the most natural way possible. By introducing certain plants, we attract beneficial insects and predators to tackle pests, or we use organic pesticides (like pheromones or insect traps). These practices can boost the resiliency of your orchard and make pests and diseases less of a problem.

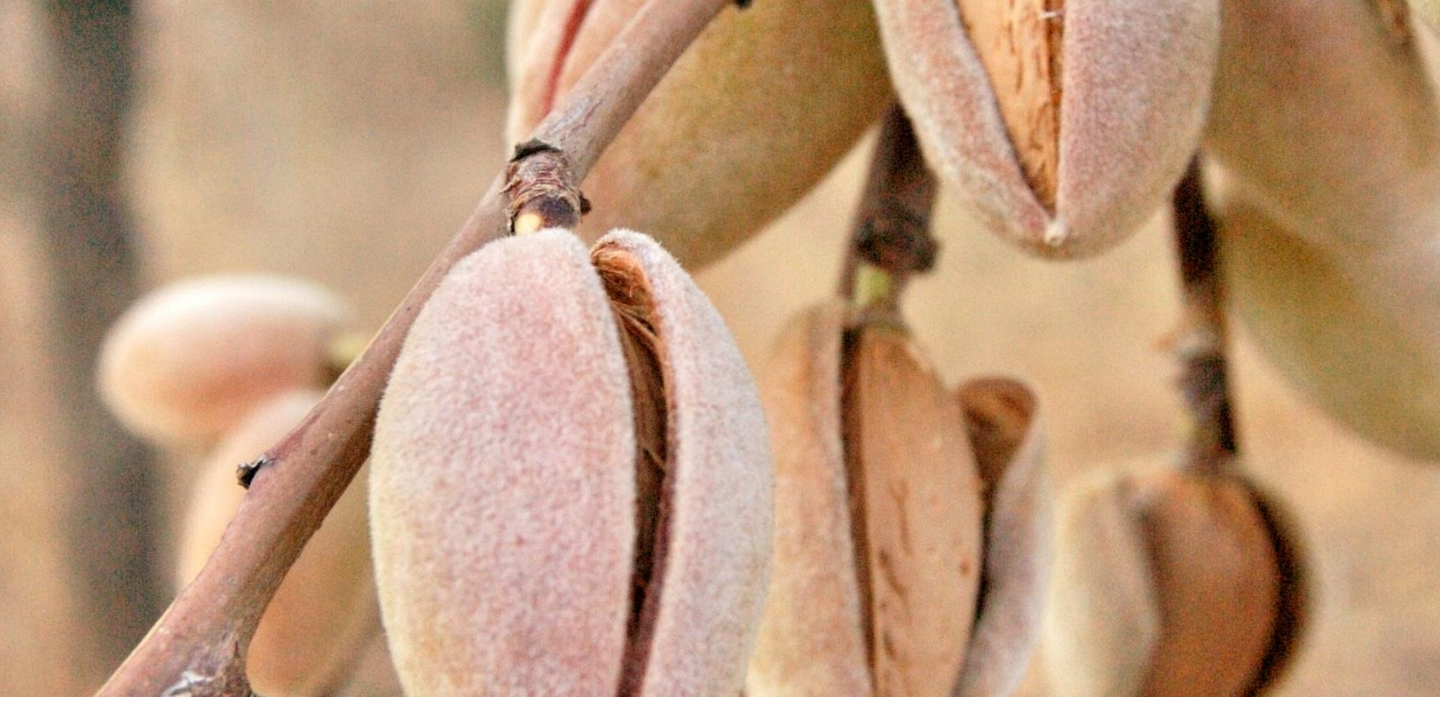
Note: some pests don't have natural predators and are more of a challenge – eg. the gusano cabezudo (Capnodis tenebrionis) and the avispilla (Eurytoma amygdali).

Besides pests, almonds can also suffer from diseases. One of the most common is 'mancha ocre', which occurs in spring, when temperatures are favourable and the rain spreads fungal spores that infect newly emerging leaves. Consequently, especially early varieties like Guara are more susceptible. Symptoms, which include brown/yellow spots on leaves, tend to appear after two months.

Below we see aphids on the left side and the beneficial insects on the right:

Each pest has a certain time during which it is most active. The figure below shows when to look out for each pest:





3. Regenerative Practices in Almond Orchards

In this section, we'll look in more detail at some of the most effective regenerative practices you can introduce to your almond orchard. We'll examine the costs, risks and rewards, but each practice must be considered in the context of your farm, the season and the resources available. The table below summarises the stage at which each practice is best implemented, across flat and mountainous areas:

Practice	Mountain area	Flat area	Year 0	Year 1	Year 2	Year 3	Year 4 & beyond
Swales/ponds/ sediment traps	x	-	Swales/ponds/ sediment traps				
Keyline	x	-	Keyline				
Compost	x	x	Compost				
Minimum tilling	x	x	Minimum tilling				
Natural corridors	x	x		Natural corridors			
Vegetation strips	x	x		Vegetation strips			
Ground cover	x	x					Ground cover
Livestock	x	x					Livestock

The following graph gives an overview of the different regenerative practices (across water infrastructure, soil and diversification), summarizing their respective economic and ecological impacts:

	Practice	Effects	Economic impacts	Ecological impacts		
				Soil	Water	Biodiversity
Water infrastructure	Ponds	Increased availability of water, reduced run-off	+/-	+	++	++
	Swales & sediment traps		+	++	++	+
	Keyline		+	++	++	
Soil management	Reduced tilling	Increased fertility through nutrients, micro-organisms and oil organic matter content, erosion control, increased infiltration, reduced evaporation	+	++	+	++
	Vegetation strips / Ground cover		+/-	++	++	++
	Compost		+	+++	++	+
	Pruning waste		+	+	+	
Diversification	Intercropping	Diversified operations (less risk) and increased biodiversity and natural pest management	?	+	?	++
	Integration of livestock (winter)		+/-	+		++
	Natural corridors		+/-	+	+	++
	Integration of bees		++			++

3.1 Swales

In sloped areas of the Mediterranean, terraces were traditionally used to decrease run-off and soil loss. However, these were largely been abandoned with the arrival of mechanisation and large-scale farming. Now, small- and large-scale farmers in Spain and other Mediterranean countries are showing a growing interest in swales (Holzer and Dregger, 2011; Schoonhoven, 2017). Swales can only be made *before* planting the almonds, as the swale will determine the course of the plantation. Swales must also be well-spaced enough to allow a tractor through, so from the steepest point, measure a minimum of 20 meters to the next swale. Bear in mind that swales should be created at a point where the rainwater has started to erode soil; if made too high, the swale won't have an effect.

Potential for experimentation

As swales are a relatively new concept in Mediterranean countries, long term data on their effectiveness is still lacking. Consequently, it is useful to study how swales impact groundwater levels; how much erosion of fertile soil is prevented; how swales impact the growth of the trees and where exactly (in relation to the swale) these effects are observed.

Introduction to practice	Swales are gullies/trenches along a contour line (contour trenches). They store part of the run-off and give the water time to infiltrate. The volume of the swale is the volume of run-off it can harvest. This harvested water will infiltrate and can move laterally through the soil - how far will depend on soil characteristics like the saturated hydraulic conductivity (ks) and the slope.
Expected ecological impact over time	1. Retain rainwater 2. Stop erosion 3. Act as natural corridors 4. Diversify plots
Expected economic impact over time	The effect on profit in a dry year will be particularly noticeable, because in dry years, the water stress is higher and the water harvested in the swale has a greater impact.

Swales

Interaction and dependency on other elements	The efficiency of swales depends on the soil type (they fill up faster in clay soils) and the depth and width of the swale.
Application & prerequisites	Swales are made on slopes with a laser, a tractor and a polidozer. If you do not have a laser you might want to try it with an A frame. It is important to make the swales before planting any almonds, and to locate them in the right areas of the plot.
Orchard conversion	It is difficult to implement swales on an existing plot (where trees are already planted) because they will change the route of the tractor. That means it might be a lot more work to till/harvest/fertilize the plot when there is a swale crossing the plot. It is not impossible, but it might be necessary to remove trees. As a second best you can add **sediment traps,** which require a lot less space.
Cost, implementation & maintenance	Everyone can learn how to make a swale. At La Junquera (one of our featured farms) the cost of one swale comes down to around 100,- EUR (which includes the cost of the tractor and the tool). It takes about 2 - 3 hours to design and prepare a swale.
Risks	1. The swale can collapse during a high-intensity rainfall event 2. If the swale is too small, it may overflow in a small rainfall event 3. If the swale is made in the wrong spot, it might not collect water
Combinations with other practices	1. Aromatics and other bushes/trees can be planted on the swale to increase biodiversity and habitats for beneficial insects 2. Swales can be connected to ponds or sediment traps to harvest excess rainwater

3.2 Ponds

Ponds contribute much more than just water. They provide a host of benefits for the farm, including opportunities for recreation, tourism, biodiversity, resource recycling and irrigation. They can also open the door to diversified production: for example, growing fruit trees that need a lot of water. It's important to monitor the water quality of your pond, as it will have an impact on many of the functions listed above.

Maintenance

You'll need to maintain your pond over the years. Over time, heavy rainfall might cause the pond to fill with sediments; the speed of this process will depend on the management of the rest of the plot (e.g. does it have swales, vegetation strips, sediment traps). When the pond fills up with sediments, these can often be removed with an excavator and the (fertile) sediments spread throughout the plot. Failure to remove the sediments will reduce the pond's water retention capacity. Heavy rainfall may also cause the collapse of the pond's structure (eg. the dam). When this happens, you'll need to repair the damage when the area around the pond is dry: the summer months are best for fixing water works.

To monitor water quality in the pond, look at salinity, nitrate levels and pH levels. Salinity is a good measure of whether the pond water can be used for irrigation in case of severe droughts, while a very high or very low pH can make your pond toxic for biodiversity. Salinity and pH are fairly easy to measure with garden tools.

Potential for experimentation:

1. The relationship between ponds and pollinators has been studied by various scientists, with conflicting results (recording both positive and negative effects of ponds on local bee populations). Why not collect your own data?

2. Consider investigating the effect of ponds on natural pest control in almond orchards.

Ponds

Introduction to practice	Ponds can be natural or man-made water bodies in strategic points on the farm. They catch rainwater and are usually created in mountainous areas.
Expected ecological impact over time	1. The hydrological cycle is altered by these small bodies of water. After large rain events (which happen occasionally) water is retained on the farm, rather than running off straight away to lower areas. 2. Wildlife is attracted for multiple reasons. Firstly, the surface water is one of the few sources of drinking water in the area. Secondly, the ponds host a large variety of aquatic life that directly or indirectly serves as a food source for terrestrial animals. 3. Ponds affect the local climate by elevating the humidity or lowering temperatures 4. By recycling nutrients and chemicals, ponds purify the water supply
Expected economic impact over time	Ponds can result in: 1. Increased crop production around the ponds 2. Increased water availability for irrigation purposes 3. Recharged groundwater
Interaction and dependency on other elements	Ponds are normally created in hilly areas as they need to catch the rainwater of the surrounding water catchment to fill up. They fill and retain water more easily when made in areas with clay soils. The sediments entering the pond can make it watertight over time and need removing. The type of dam and/or border of the pond will define the amount of water that infiltrates the soil.
Application & prerequisites	There are ponds that serve maintenance functions, such as sediment/water traps. By choosing the right design and location, your ponds can do their job properly. The depth and size can affect the likeliness of a pond being in a clear or a turbid state, which can affect the functioning of the pond. Consider: • How big is the water catchment? This will tell you how much water the pond will receive in the case of torrential rain. • How big should the overflow be? Make sure the overflow is big and wide enough to handle torrential rains. • Does the pond need a mud trap to catch the sediments before entering the pond? (personal preference)
Orchard conversion	Including a pond in an existing orchard might mean taking out some trees to make space.
Costs implementation & maintenance	Ponds can be very expensive or relatively cheap depending on the site, soil and purpose. Many smaller ponds made in gully areas can be made for less than 200 EUR/pond with an excavator and a tractor. Bigger ponds with layered dams might cost up to 10.000 EUR/pond.

Risks	1. Sometimes, a pond does not retain the rainwater because it is not watertight (in sandy soils, for example. 2. The clearance of natural vegetation (allowing groundwater salts to reach the surface) can cause salinization and the rising of saline groundwater levels. 3. Water quality can shift from a clear to a turbid state, impacting the aquatic ecosystem and pond functionality 4. If run-off water is collected from conventional neighbouring farms, the water might carry pesticides that will be accumulated in the pond 5. The dam might burst with heavy rainfall
Combinations with other practices	Ponds can be used in tandem with swales and sediment traps. By designing a plot with a series of these practices, the water that finally ends up in the pond has already been filtered and infiltrated by the swales and sediment traps, therefore entering the pond with less force and less turbidity.

Ponds at the border of almond field, created (L) July 2017, (R) May 2020.

Example: Designed by Sepp Holzer, Vivencia Dehesa has built ponds to build up their water reserves and attract wildlife. The ponds connect to each other and provide different habitats for animals, as well as changing the microclimate.

3.3 Keyline design

The central idea behind keyline design is to capture water at the highest possible elevation and channel it outward toward the ridges taking advantage of gravity - reversing the natural concentration of water in valleys. The flow of water to the drier ridges is maximised using precise plough lines: falling slightly off-contour slows the movement of water and spreads it more uniformly, infiltrating it across the broadest possible area. Instead of following contour lines (which can create fragmented landscapes) all the lines in this design are parallel, making it easier for machinery to work the land.

Keyline design typically employs water storage devices (usually ponds) as a component of the overall plan. Small ponds of surplus run-off water can be placed at the natural intersection of a ridge and a valley. This stored water provides gravity-fed irrigation later in the season for pastureland or crops.

"The slope of each line should be 4%, in order to be able to carry the water from the valleys to the ridges (the 'drier' parts of the land). On sandy soils, which have high infiltration capacity, the slope can also be increased to 6%, as water infiltrates the soil quickly, so we need to move it faster."

-Matteo Mazzola - Agronomist-

Keyline Design

Introduction to practice	Keyline design integrates terraces, ponds, tree plantings on contour, and a special cultivation technique to filter water into the soil efficiently and retain it as long as possible.
Expected ecological impact over time	1. Build and restore degraded soils 2. Prevent run-off and erosion 3. Divide rainwater more equally over the plot and hold more moisture in the soil 4. Increase fertility of the soil 5. Groundwater recharge

Expected economic impact over time	Rainwater will not be lost, but used by the trees - so production can be greater, while external water use is reduced.
Interaction and dependency on other elements	Depends on the soil type, machinery available, spacing between trees and size of the plot.
Application & prerequisites	Keyline and the use of the Yeomans plough have been successfully applied to different land uses. The Yeomans plough is especially useful on highly compacted soils of any grade, where it substantially increases infiltration and soil fertility, and reduces erosion and run-off.
Orchard conversion	It is not possible to use keyline design on an existing almond orchard.
Costs implementation & maintenance	Tilling can cost up to 2x more time compared to conventional plots.
Risks	To avoid costly manoeuvring of machinery, don't apply keyline on slopes which are too steep. Implementation with heavy machinery can lead to soil compaction/soil disturbance. Keyline is a fascinating technology, but it's not appropriate everywhere. One farmer in Catalonia reported that his almond tree plantation (non-irrigated and using keyline design) suffocated after a seasonal heavy rain. The plantation was located at the lower part of a water catchment area, with heavy clay soils. Almond trees are very sensitive to waterlogging, so we suspect the keyline design was counterproductive, as it did not drain the excess water from the plot.
Combinations with other practices	Retention ponds can be used in combination with keyline design, collecting the water coming from roads designed on keylines.

3.4 Compost

Compost is humus-like material made from decayed organic matter through the activity of soil microorganisms. It is often made of manure, straw, ashes, sugar and water. Mature compost retains its quality for a long time and stores well, without smelling bad. In agronomic and horticultural operations, compost can be used as a soil amendment, seed starter, mulch, container mix ingredient or natural fertilizer, depending on its characteristics. Composting can also reduce or eliminate weed seeds and plant pathogens in organic residues. In the Mediterranean, compost can have a significant impact on soil fertility. This is because the region's fertile soils have been lost as a result of excessive tilling, bare soils and other harmful farm management practices.

Homemade compost on La Junquera farm: 40% straw, 60% manure, sprayed microorganisms from the forest, sugar, ashes and water help to raise humidity levels to 70% (for every 100 cubic meters compost 1L sugar)

Biodiversity on an almond farm in El Contador. Beetles are a sign that the soil is alive.

Maintenance & Tools

If the compost is made on the farm, it can be helpful to buy or rent a compost turner. To spread the compost, you'll need a tractor and trailer or a compost spreader on larger farms.

Implementation of composting will vary according to the specific farm context.

Compost

Introduction to practice	Compost is created from the aerobic decomposition of many materials usually considered waste, including food scraps, animal manure, leaves, straw, and more. Composting occurs when carbon-rich materials ("browns"), like straw and leaves, are mixed with nitrogen-rich materials ("greens"), like food scraps and manure. Add oxygen, time, some skilled management and the help of billions of microorganisms – and the finished result is crumbly, sweet-smelling, nutrient-packed compost.
Expected ecological impact over time	1. Increases microbial activity 2. Enhances plant disease suppression 3. Increases soil fertility (higher N & K because of compost) 4. Increases CO2 capture 5. Improves soil structure in clay soils 6. Improves water retention in sandy soils 7. Reduces bioavailability of heavy metals
Expected economic impact over time	A recent study demonstrated that, under current economic conditions, compost application drove the highest long-term profitability of almond farms in Mediterranean Europe, with the shortest payback time.
Interaction and dependency on other elements	When planting almond trees, you can either add your compost directly under the root or next to the tree after planting. Adding compost to the roots can be risky if the soil doesn't have good drainage (eg. with clay soils). You should also ensure that the compost is very well composted before adding to the roots, or the roots may burn.
Application & prerequisites	You can use a tractor with a trailer to introduce your compost, or do it by hand on a smaller scale.

Orchard conversion	Compost can act as a substitute for chemical fertilizers – but remember to always analyse the specific micronutrients your trees need before adding any type of fertilizer.
Costs implementation & maintenance	50 EUR/ha for conventional compost and 105 EUR/ha for organic regenerative compost, per year.
Risks	Applying immature compost to the plot can inhibit plant and root growth, and decrease oxygen concentrations which decreases root respiration.
Combinations with other practices	Compost can be used to boost the effectiveness of vegetation strips and reduce competition between vegetation and tree.

3.5 Minimum Tillage

The objective of minimum/conservation tillage is to disturb the soil a little as possible to boost crop production. In this method of tillage, seeding and tilling are often done simultaneously and the soil is not turned. Reduced tillage can mean tilling fewer areas – eg. tilling only the rows/ailes of the orchard. It can also mean tilling less frequently – eg. two or three times a year, rather than five. (With the addition of a winter ground cover, this might involve tilling only in April/May and after the harvest.) Finally, reducing the depth of the tilling to a maximum of 20cm also has a big positive effect on soil health.

No Tillage

More self-explanatory, the practice of no tillage is often combined with the use of a cover crop or ground cover. The challenges of a no-till system are most acute in dryland systems, where production can suffer. But in irrigated systems or areas with more than 500mm rainfall a year, no tillage is more feasible.

Minimum Tillage

Introduction to practice	Minimum tillage means disturbing the soil as little as possible for a successful crop production.

Expected ecological impact over time	1. Higher biodiversity of the soil, increase in organic matter increase, fungal activity and available minerals. 2. Improved soil structure 3. Higher CO2 uptake 4. Increase soil organic carbon by 60% 5. Reduced runoff by 50% 6. Increased water retention capacity
Expected economic impact over time	Halving the amount of tillage on your farm has a huge impact on the cost of labour, diesel and tractor (rent). It can increase the soil fertility which can positively impact productivity and reduce erosion, mainly in the case of green manure and vegetation strips. Nevertheless, if done incorrectly (wrong timing, depth, etc), production can be adversely affected, with a negative economic impact.
Interaction and dependency on other elements	• When and how much to till depends on the soil. Sandy soils can be tilled less frequently than clay soils which tend to be compacted by tractors and livestock. • When it rains it is better to postpone tilling because of the risk of compaction. • If you have too many weeds, you might have to till/cut the grass.
Application & prerequisites	The first step is to start using a tilling tool instead of a plough and till with maximum 20cm depth. The need for tilling the soil varies over time. To minimize tilling, it is important to monitor your plot and analyse what is needed. In some areas, farmers start by introducing vegetation strips in the lanes of the orchard (max 2m width). These generally do not compete with the tree, but can reduce labour costs, reduce erosion and improve soil stability. From there, you can move on to wider vegetation strips and less frequent tilling.
Orchard conversion	Transitioning from conventional tillage to minimum tillage must be done with care: it is not advisable to reduce your tilling from 5 times to 2 times tilling in one year. Instead, cut down by one tilling per year until you reach one or two times per year. This gives the soil time to adapt. It is easiest to start reducing the winter tilling until there is a ground cover during the winter months (October-March/April).
Costs implementation & maintenance	There are no extra costs involved in minimum tilling other than the use of the tool and the discs or grass cutter for cutting excess weeds before tilling.
Risks	Check the plot regularly to ensure the weeds are not taking over or competing with the trees. Reducing tilling might influence the growth of the tree and production: stay vigilant on how it affects your plot. The first two years of the transition might be hard for the tree. The soil is adapting and that might cause a temporary decline in production.
Combinations with other practices	Minimum tillage can work well together with: 1. Winter ground cover 2. Vegetation strips 3. Compost

3.6 Natural Corridors

Natural corridors are thriving areas or hedgerows that line productive plots, helping to increase and maintain the functional diversity of your farm.

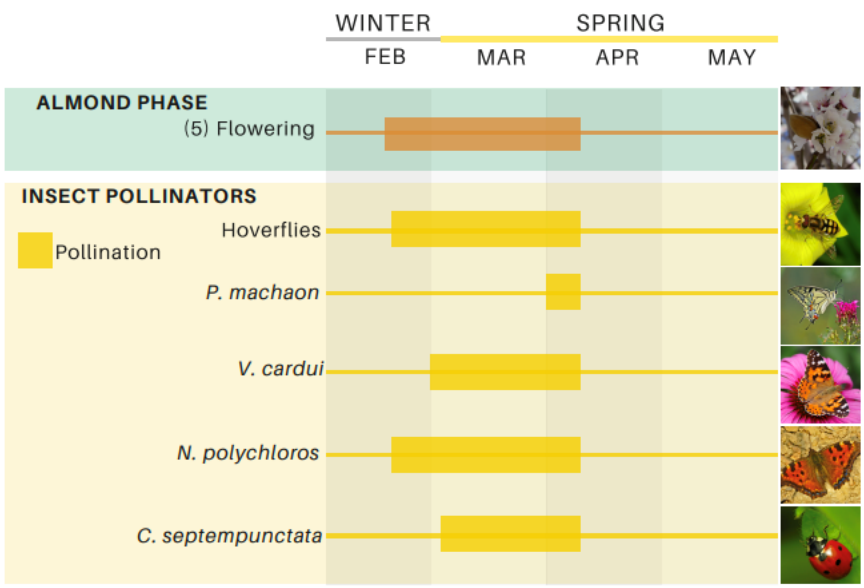
"You can measure and analyse the impact of natural corridors on biodiversity in a number of ways. For example, monitor the quantity and type of insects and plants on your plots over time. Alternatively, you can analyse the micro-biodiversity in the soil (e.g. through enzymes that carry phosphorous). If this type of biodiversity is present at soil level, your crops will benefit from that phosphorous."

Matteo Mazzola - Agronsomist

Maintenance

The amount of maintenance your hedges need will depend on the type of plants and bushes used. Some trees grow faster and more healthily if pruned; a hedge of flowers will benefit from mowing in late spring to help with reseeding.

"At our farm, we maintain the hedges for the first two years, pruning the trees and watering them in the hot, dry summers to keep the biodiversity alive. We also weed around the aromatics to help the hedge survive competing plants" *Alfonso Chico de Guzman – farmer, La Junquera*



Thesis Enya Ramirez de Valle on almond orchards (2019).

Potential for experimentation

Consider monitoring the long-term effects of the hedge on production, pest management, erosion, and other ecosystem services.

Natural Corridors

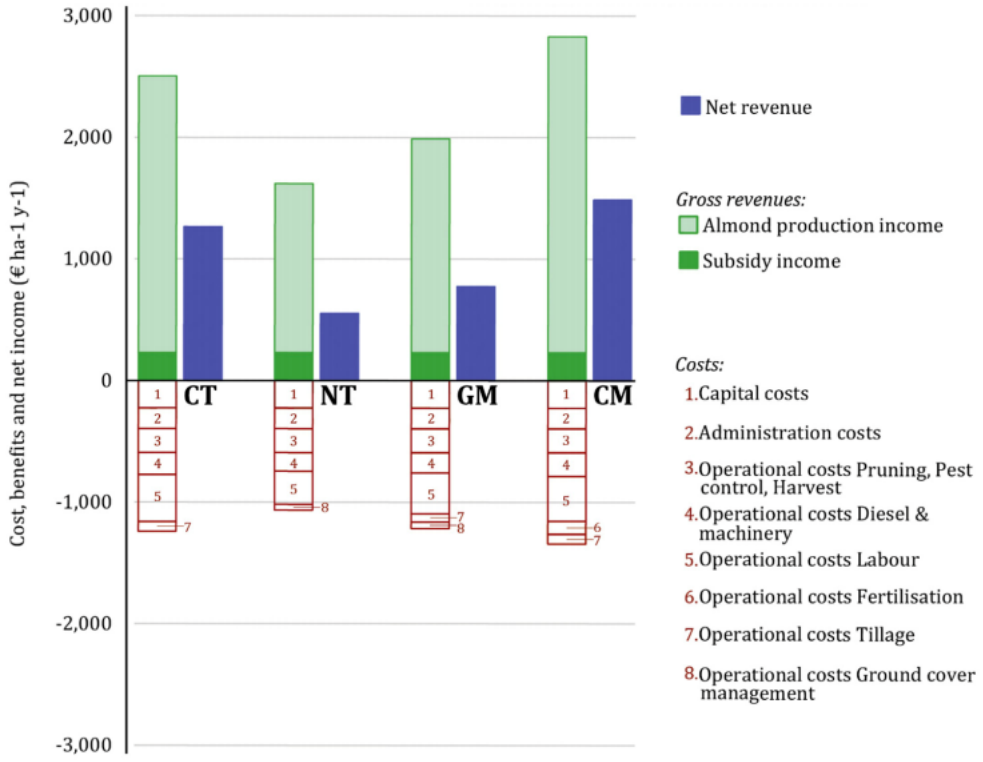
Introduction to practice	Natural corridors are planted for a variety of reasons, generally on the sides of the plot, on terraces or within the plot itself. The hedge is often a mixed line of trees/bushes/aromatics.
Expected ecological impact over time	1. Stabilize soil structure 2. Reduce erosion (wind breaks) 3. Increase soil organic matter 4. Increase nutrient content 5. Provide natural habitat 6. Natural pest control
Expected economic impact over time	Although a clear economic impact has yet to be demonstrated, hedges/natural corridors may reduce the quantity of pesticide needed. Additionally, although hedges cost money to implement, they bring many non-monetary benefits over time.
Interaction and dependency on other elements	Hedges have a positive impact on surrounding crops, as they provide a habitat for beneficial insects, helping to reduce unwanted pests. Their function is dependent on the type of plants/bushes/trees that are planted in the hedge.
Application & prerequisites	When choosing perennial species to plant in hedges, consider the following criteria: 1. The height of the plant (for the hedge's structure) 2. The flowering season (to ensure nectar and pollen in the hedges for the longest period possible) 3. The location of the hedge: side of the plot, terrace/swale or in between the almonds 4. The plant USDA hardiness for survival in winter. (Because the plant hardiness zone of the region is 9b (-3.9°C to - 1.1°C), the plants should have a USDA hardiness lower than 9.) 5. The preferred habitat, including the soil characteristics, sun exposure and resistance to dryness 6. The plant's ability to resprout from cuttings: this reduces the costs to farmers of planting hedges and so facilitates their adoption across the farm 7. The plant's ability to support pollinators and natural enemies Once you've made your choice, you can start planting (generally between autumn and spring). If it doesn't rain soon after planting (or the soil is very dry), it's important to water them. In the first year especially, you'll need to check up on your natural corridors to ensure their survival.

Orchard conversion	Hedges can be implemented on the sides of an existing plot relatively easily. Take into account that there are many regulations about the minimum space between a hedge and a road. Also make sure the tractor driver knows exactly where the hedge is planted.
Costs, implementation & maintenance	This depends on the amount of plants/bushes/trees that will be planted per meter. At La Junquera (one of our case study farms), hedges contain 1000 plants/km at the following cost: • Preparing soil: 0,50 EUR per plant • Plant: 0,50 EUR • Watering: 0,50 EUR per plant • Labour: 0,20 EUR per plant • Compost/protectors: 0,50 EUR per plant The idea is to keep maintenance costs low. Nevertheless, in the first year, keep an eye on your plants – and if it is a very dry summer, you might need to irrigate them once or twice to give them the best chance of survival.
Risks	For groves with small almond trees, avoid competition with the primary crop.
Combinations with other practices	Natural corridors or hedges can be planted on swales, terraces or around ponds or sediment traps and that way become islands of biodiversity.

3.7 Ground Cover

Cover crops can be an indispensable tool in maintaining and increasing soil fertility without using chemicals, and in decreasing the amount of nutrients that need to be added. Certain seeded cover crops act as green manure and have the unique ability to "fix" nutrients (like nitrogen) from the atmosphere and return them to the soil by tilling. Cover crops also help smother weeds, control pests and diseases, enhance water availability, and increase biodiversity on the farm. Think of them as a living mulch.

A recent study (Ramos et al) showed that cover crops in semi-arid environments improve the soil quality compared to frequently-tilled soils. This is because cover crops increase the organic mater content, boosting the chemical and physical fertility of the soil and enhancing the soil's biological activity. The only risk to orchard development/productivity is that the plants could extract too much water – but removing the cover crop early can minimise this potential loss of yield.



Difference in costs and benefits between different management practices in Southern Spain: CT: conventional tillage, NT: no tillage, GM: green manure, CM: Compost management (Vincent de Leijster)

Natural ground cover is ground cover that grows naturally in hedges, terraces, between trees, or in the aisles between the tree rows. It can be left to grow all year round or only in winter. The implementation of this practice depends on the amount of rainfall and soil fertility, and consequently on the reaction of the trees to the ground cover. With year-round ground covers, production is likely to be reduced, but biodiversity increased. Green manure (or 'winter ground cover') increases the organic matter in the soil faster as it is incorporated in the soil on a yearly basis.

Ground covers are more easily implemented on irrigated fields because they will compete less with the tree crop. But they can be very beneficial when used in dryland systems because they capture rain water, prevent evaporation and stop erosion. It's a challenge to find the right balance – one that requires active feedback mechanisms and careful planning.

Maintenance

This type of ground cover can be managed with discs, cutting or mowing tools, livestock or a superficial tilling tool. When cutting the weeds/grass, leave the residues on the field as mulch to retain moisture and protect the soil from the sun.

In the case of natural ground cover, you can leave the natural vegetation that springs up untouched. However, you can also manage it to prevent competition, especially in spring and summer. The biggest challenge is the competition for water and nutrients between the ground cover and the almond trees. It's important to test and understand the specific balance for every orchard, making sure that the ground cover does not diminish production. To ensure as little competition as possible, sow different vegetation covers with complementary growing cycles.

Ground Cover

Introduction to practice	Ground cover (or 'vegetation strips') means covering part of the soil with plants during part of the year. There are different types of ground cover: 1. Naturally occurring 2. Seeded vegetation 3. Different types of management 4. Vegetation strips or total cover 5. Summer and/or winter cover 6. Green manure (vegetation is tilled in the soil in spring)
Expected ecological impact over time	• Less erosion, better soil quality, increased water retention, soil decompaction • Stable or higher production • 50 % less run-off on the farm • Reduces topsoil loss by 74% • Improves biodiversity by 60-140%, including an increase in wild pollinators, bird species and other insects, and the provision of habitat for threatened species.
Expected economic impact over time	• If they are implemented well, ground cover/vegetation strips have limited to zero negative economic effect. And as they reduce erosion, they can save the costs of losing fertile soil. • Winter ground cover or 'green manure' can decrease production slightly, but in the long term it will improve soil organic matter and reduce erosion. • At La Junquera, the winter ground cover does not have a negative economic impact. • Year-round ground cover/no tilling does have a negative economic impact, as the production in dryland orchards can go down with 30% or more.

Interaction and dependency on other elements	Effectiveness depends on total rainfall, width of vegetation strips, contour planting, type of seeded cover and vegetation management.
Application & prerequisites	Two options: 1. Sowing a mix of legumes (nitrogen fixers) and cereals 2. Allowing natural vegetation to grow
Orchard conversion	When introducing ground cover to an existing orchard, it is best to test and learn. Start by planting vegetation strips on part of the plot to see how it works: some farmers plant in the streets between the orchards, while others leave them in the rows of trees. This choice comes down to personal preference and the machinery available. Consider starting with vegetation strips before moving on to a full winter ground cover, to see how your trees respond.
Costs implementation & maintenance	• In a plot with some natural ground cover, tilling costs are comparable with tilling the entire plot. • When using seeded ground cover, there are costs involved in 1) seeding and 2) cutting the vegetation strips just before summer/ let sheep graze there in the winter • You'll need a tractor to till near the vegetation strips to make sure they don't compete with the trees for water. • With full ground cover, a cutting machine is needed; alternatively, livestock can be integrated in the system (easiest in winter).
Risks	If competition for water between vegetation strips and tree crops is too high, the tree growth might be affected. Year-round ground cover increases this risk. Weeds can grow that may attract pests.
Combinations with other practices	Vegetation cover can work together with: Compost; Integration of Livestock; Swales & Terraces (leaving the area around the swales/terraces unploughed). The practice of intercropping with aromatics is still being tested.

3.8 Integration of livestock

In almond orchards, the integration of livestock generally means letting a flock of sheep or goats graze in your orchard, fertilizing the land and ´mowing´ the weeds. You might own the animals yourself, or you can rent out the land to a shepherd. Generally, the sheep graze the land for part of the year: in southern Spain, this tends to be Autumn to Spring. You'll need around 1 hectare of grazing area per sheep, depending on the nutritional value and biomass produced by the ground cover or cover crop. Seeded ground cover or cover crops are ideal for livestock as they contain more nutrients. If managed well, cover crops will reseed themselves annually. In the Altiplano of southern Spain, a combination of barley, vetch and bitter vetch has worked well, with one or two tillings a year (depending on the contextual factors of the farm).

Maintenance

If sheep are left to choose their food freely, they will leave the weeds in favour of tastier plants – letting weeds take root across your land. So the objective is to ensure that the sheep graze long enough in one place to eradicate the weeds – but not so long that they start eating the trees! The shepherd plays a crucial role in managing this process, and achieving the right grazing balance for the land. Livestock are less likely to destroy the trees if they graze in winter, or if the trees are pruned high enough.

Integration of livestock

Introduction to practice	Livestock are integrated in almond orchards. In the south of Spain, this means sheep grazing in and around the orchard in the winter months. Depending on how the trees are pruned, they might graze over the summer too.

Expected ecological impact over time	• Increased soil fertility • Sequester carbon • Weed management • Ground cover helps tackle soil erosion • In natural areas, grazing can help to prevent fires
Expected economic impact over time	Can provide an additional income stream (diversification) as shepherds normally pay to use the plot for grazing. Grazing ground cover is cheaper than tilling in the winter.
Interaction and dependency on other elements	Your ability to introduce livestock to your almond orchard will depend on the nutritional value, biomass, quality and carrying capacity of your ground cover/cover crops - which will depend on rainfall and the seedbank. If the goal is to also have sheep grazing in spring and summer, your trees should be pruned at 1.10 or 1.20M so the sheep do not eat the fresh leaves. The shepherd plays a big role in making sure grazing doesn't harm the trees.
Application & prerequisites	You will either need to buy your own sheep or collaborate with a local shepherd. Bear in mind that owning your own sheep requires a full-time presence and suitable skillset. Both natural and seeded covers are suitable for grazing, but a combination is generally best. For seeded covers, oats, barley, vetch and bitter vetches work well in dryland areas, and you can seed them together or separately.
Orchard conversion	To include livestock in an existing orchard, you'll need to start by implementing ground covers (see the relevant section in this manual).
Costs implementation & maintenance	Whether you partner with a shepherd or use your existing livestock, introducing grazing animals to your orchard will usually bring in revenue without costing a thing. But bear in mind that you will need to spend time planning the grazing and that a shepherd will need to be with the sheep while they are in the orchard.
Risks	Livestock may harm the trees if there is not enough nutrition in the ground cover. (See also: Risks of ground cover)
Combinations with other practices	1. Ground cover/cover crop 2. Making compost/adding manure

4.0 Example projects and farms

- La Junquera farm, Southern Spain, www.lajunquera.com
- Cortijo el Puerto (biodynamic farm), Sevilla Spain, https://www.cortijoelpuerto.com
- Almendrehesa, regenerative almond cooperative Spain, www.almendrehesa.es
- A diverse farm on keyline in Menorca: www.sonfelip.com
- A sustainable, organic and biodynamic almond farm in Italy. https://clubdellamandorla.it/club-della-mandorla/#

La Junquera - Murcia

La Junquera is a family farm in dryland Southeastern Spain. They are leading the way for regenerative agriculture, showcasing its potential and providing tools for a transition to healthier soil and more effective land stewardship.

“In the past, our 1100 hectare farm grew only grains and we could barely cover the costs. Now, we’ve diversified our farm business with almonds, pistachios, aromatics and apples. First we went organic, and now we’re implementing a lot of regenerative practices to capture water and increase soil fertility. It has become a lot more complex to live on the farm – but a lot more fun.”

Area (ha)	Harvest	Management	Market & prices
La Junquera manages 630 ha of almonds in total (since planting 5 years ago). The farm is at 1100m altitude, 350L rain yearly and frost from September until may.	In shell: 700 kg/ha after year 6.	Tilling 3 times a year, vegetation strips, keylines, fertilizer from pallets (lavinor N-10,10), organic pesticides, compost (self made with mainly sheep manure), implementation of pollinators (400 beehives).	Tilling 3 times a year, vegetation strips, keylines, fertilizer from pallets (lavinor N-10,10), organic pesticides, compost (self made with mainly sheep manure), implementation of pollinators (400 beehives).

"Our almond trees are 40 years old. We plant the seed and graft on it, in the traditional way. The almonds are planted together with olives, so there is always something to sell and it improves the aesthetic of the landscape for tourism. The farm has terraces which help protect against erosion and improve the trees' water availability. We use green manure twice a year, and compost on a bi-yearly basis because of the higher cost. Luckily, our neighbour's sheep pass through the farm once a year as well and graze the land and fertilize it."

Zisolhouse, Sicily

4

Useful Resources:
Almonds

Reference Resources:

- AlVeLaL farmers: a blog about the regenerative almond farmers in dryland southern Spain and their farms. **https://www.alvelal.net/blog/categories/rostros-alvelal**

- *Evaluation of breaking dormancy, flowering and productivity of extra-late and ultra-late flowering almond cultivars during cold and warm seasons in South-East of Spain*. Prudencio, A. S., Martínez-Gómez, P., & Dicenta, F. (2018). Scientia Horticulturae: 235, 39–46.

- Organic management of Almonds in Italy, chapter 6 on varieties: **https://www.coltivazionebiologica.it/coltivazione-del-mandorlo/#Varieta_di_mandorli**

- Organic management of Almonds in Spain, chapter 6 on varieties: Guías de Agricultura Ecológica del Proyecto mayas. **http://www.agroambient.gva.es/documents/163228750/169854879/Guia+de+Cultivo+Ecol%C3%B3gico+del+Almendro-+2011-Proyecto+Mayas.pdf/2828960b-b82c-462d-8994-a9129e9d95c0**

- Overview of most important plagues in almond orchards: **https://www.agromatica.es/plagas-y-enfermedades-del-almendro/**

- Research on plagues and natural pest management in almond orchards: **https://drive.google.com/file/d/1x7lAn9hHUfVx5H_KmcwiQswO05drbumr/view**

- Linea Clave Keyline: This video shows what an almond orchard designed on keyline could look like, using a real example from Toledo. See the YouTube channel for more examples: **https://www.youtube.com/watch?v=bp_O4maxB4E&ab_channel=LineaClaveKeylin**

- *Water For Every Farm: Yeomans Keyline Plan* by P.A. Yeomans (2008)

How to deal with erosion in almond plantations:
https://www.fega.es/sites/default/files/imported/PwfGcp/imagenes/es/Fega_Manual_Almendro_tcm5-30195.pdf

How to make compost: this website by the Andalusian government gives a good overview of how to make compost.
https://www.juntadeandalucia.es/export/drupaljda/boletin_compostajecompleto.pdf

The Rodale institute on how farming practices should include composting.
https://rodaleinstitute.org/why-organic/organic-farming-practices/composting/

The use of cover crops and green manure in dryland almond orchards: *Cover crops under different managements vs. frequent tillage in almond orchards in semiarid conditions: Effects on soil quality*. Ramos, María E., et al. Applied Soil Ecology 44.1 (2010): 6-14.

Making compost in organic farming, an overview of compost making techniques in the US**. https://eorganic.org/node/2880**

Seeded and natural ground covers in almond orchards, Guia Carbocert 2020:
https://guiacarbocert.es/wp-content/uploads/2020/08/guia%20carbocert%20para_web.pdf

An overview of the impact of different tillage systems in Europe: *The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence.* Holland, J. M. Agriculture, ecosystems & environment 103.1 (2004): 1-25.

Profitability of ground covers and other management systems: De Leijster, V., Verburg, R. W., Santos, M. J., Wassen, M. J., Martínez-Mena, M., de Vente, J., & Verweij, P. A. (2020).

Impact of ground cover on the soil: Leijster, V., Santos, M. J., Diaz, M., Wassen, M. J., Belen, A. B., Ramos, M. E., ... & Mosquera-Losada, M. R. (2018). *The impact of soil and vegetation management on the rehabilitation of ecosystem services in almond orchards.* Manual on ground cover implementation, Carbocert: **https://guiacarbocert.es/**

Almond farm profitability under agroecological management in south-eastern Spain: Accounting for externalities and opportunity costs. Agricultural Systems, 183, 102878.

Impact of no tillage on crop yield: Martínez-Mena, M., Garcia-Franco, N., Almagro, M., Ruiz-Navarro, A., Albaladejo, J., de Aguilar, J. M., ... & Querejeta, J. I. (2013). *Decreased foliar nitrogen and crop yield in organic rainfed almond trees during transition from reduced tillage to no-tillage in a dryland farming system*. European journal of agronomy, 49, 149-157.

Example of the inclusion of livestock in almonds: Santiaga Sanchez Porcel **https://www.alvelal.net/single-post/2017/01/25/Los-rostros-de-AlVelAl-Santiaga-Sanchez-Porcel**

Inspiration on holistic grazing by the Savory institute: **https://savoryinstitute.teachable.com/**

Regenerative farming in action:

La Junquera: have been making swales in grain fields for the past 4 years while learning and improving the design. For more information, pictures and research check the website of the Regeneration Academy. **https://www.regeneration-academy.org/water-management**

The team at La Junquera has also constructed many small and big ponds in the past years to increase biodiversity, stop sediments from washing away and increase water uptake through infiltration **www.lajunquera.es**

Sepp Holzer: An expert on water management and permaculture. He has designed many ponds on farms in different ecosystems, both in the North and South of Europe. **http://directoryofpermaculture.com/permaculture-personalities/sepp-holzer/**

Vivencia Dehesa: this video explains the use of regenerative techniques like swales to collect and infiltrate water. Video by Miguel Blanco Gil. **https://www.youtube.com/watch?v=KDOFkKI_doc&app=desktop&ab_channel=VivenciaDehesa**

Vivencia Dehesa: has constructed ponds designed by Sepp Holzer. These ponds provide many ecosystem services. Check their website for more information on the role of ponds in a farm ecosystem: **https://www.vivenciadehesa.es/**

Water Stewards (based in California): this website gives a good overview of the different aspects of implementing keyline design, as well as links to more information**:** **http://agwaterstewards.org/practices/keyline_design/**

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