MASTER PLAN

WATER MANAGEMENT IN THESSALY

IN THE WAKE OF STORM DANIEL

How to Address Thessaly's Water-Related Agricultural Challenges

VOLUME IV: AGRICULTURE & LIVESTOCK

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Introduction

This volume outlines the recommended measures that have as its primary aim how to achieve a long-term, wholistic change in Thessaly. The plan comprises measures that will lead to a positive transformation for the sector and will be combined with measures to be taken by several other governing bodies, i.e., ministries, to help develop and evolve the agricultural value chain. This volume, while describing just the part relating to the cultivation of foodstuffs, must be considered in light of the additional measures. For example, there will be actions to enter into large-scale offtake contracts with international buyers and there will be attempts to bring to the region investments into various business in the value chain like cold storage facilities and logistical infrastructure; new technologies such as IQF lines and other forms of vertical integration to strengthen the value chain will be adopted.

Changes are advised herein regarding changes to crop selection so as to tackle the water deficit issue and create greater water security in Thessaly, which might affect all high water consuming crops cultivated in the region. At the same time avoiding loss of income for the farmers is a key aspect. Further, not one single crop is targeted, but a systemic change is required with a focus on more economically effective crops, in order to safeguard the agricultural economy in Thessaly. In some areas the changes will need to be substantial, but they will likely not need to be implemented in the entire region.

This volume posits a transition period of 6 years and the ambition is to implement the changes only in the areas where it is absolutely necessary and for it to have the least amount of impact as possible on farmers.

The agricultural area in Thessaly spans approximately 430,000 hectares, of which approximately 250,000 hectares are irrigated land. The main sectors are livestock and cultivation of cotton, maize, wheat, pasture, fruits, and vegetables, constituting a substantial part of Thessaly's economy, see Table 1: Agricultural shares in Thessaly's economy.

Crop/Animal	Economic share in Thessaly (%)	Arable land share	Share of irrigation water	Relative productivity of land (relative EUR/Ha)	Relative productivity of water (relative EUR/m3)
Durum wheat	1.9%	32%	10%	0.5	1.6
Maize	3.3%	5.8%	12%	5.0	2.5
Cotton	12.8%	24%	33%	4.6	3.4

Vegetables	22.6%	2.8%	3%	71.7	57.9
Fresh Fruit	15.6%	9%	4%	15.1	31.3
Ruminants	4.7%	13.6%	37%	3.0	1.1

Table 1: Agricultural shares in Thessaly's economy

Table 1: Agricultural shares in Thessaly's economy shows the roles that the major crops and ruminants currently play in Thessaly's economy ((ELSTAT), 2020). It also shows the distribution of irrigation water over the mentioned categories. One can clearly see that the roughage for the ruminants (including alfalfa) uses up substantial amounts of water (Hazigiannakis, 2020) and that the cultivation of cotton significantly contributes to high water consumption, driven by its substantial water requirements and extensive acreage. The economic productivity per unit of land and per unit of irrigation water is illustrated in the final two columns. Among them, horticulture featuring vegetables and fruits stands out markedly as the most economically viable and beneficial. Given Thessaly's restricted water availability, the economic growth potential lies primarily in horticulture, albeit at the cost of diverting water from the other agricultural sectors.

In the aftermath of Storm Daniel's extensive devastation to Thessaly's agricultural infrastructure, there is an urgency to reconstruct the sector. Numerous farms and processors have experienced devastating losses, including the complete destruction of livestock, valuable assets, and, in some cases, processing factories. This has left their businesses at a standstill.

Instead of merely restoring the farms and factories to pre-storm conditions, it is very strongly advised to capitalize on the opportunity to rebuild in such a way that one enhances the resilience of the affected areas. There is an opportunity now to re-shape Thessaly's agricultural sector and make it sustainable from a water usage standpoint. The previous volumes in this report have outlined measures to mitigate and adapt to flooding. Thessaly's agricultural sector is particularly susceptible to droughts, and the installation of irrigation systems, intended to alleviate water scarcity, has led to the overexploitation of the region's groundwater resources. Urgent reforms are therefore imperative in both the agricultural and livestock sectors. Adaptations to land use are crucial to address current and anticipated challenges in water management, profitability, and competitiveness.

In order to "*Build Back Better*", it will be necessary for all stakeholders in Thessaly to make significant tactical and strategic changes to their way of working.

The current irrigation water consumption in Thessaly is twice the sustainable level. Out of the approximately 1,500 million m^3 total annual water usage in Thessaly, agriculture accounts for over 90%. Reducing agricultural water use by 50% in Thessaly is not an easy option; Interbasin water transfer from the Achelous Basin to the Pineios Basin would likely be needed to ease the water stress in Thessaly. However, it is crucial to note that such a plan cannot be unilaterally formulated by stakeholders in the Pineios Basin alone. The development of a comprehensive plan requires collaboration and involvement of stakeholders from both basins.

Utilizing enhanced rainwater in agriculture as a substitute for groundwater will be necessary through the construction of dams in the upstream regions of Thessaly. This intervention would reduce abstraction levels of the soon-to-be-depleted groundwater and decrease the energy costs associated with irrigation (gravity-driven conveyance of water to the fields is far more energy-efficient than pumping groundwater from hundreds of meters below ground).

Moreover, strategically combining these dams will serve a dual purpose, acting as a preventive measure during extreme weather events such as Storm Daniel. By capturing and regulating water peaks, the dams will contribute to mitigating the risk of flash floods downstream.

Furthermore, it is imperative that the irrigation water per farm be minimized while concurrently enhancing individual farm revenues. Exploring various combinations offers the potential to reduce overall water consumption while simultaneously increasing their total income. Thessaly's favorable agronomic conditions make it conducive for the development of a horticultural sector, where significantly higher income is generated per cubic meter of water used. A single hectare dedicated to horticulture will likely yield more income than five hectares of traditional arable crops such as cereals and cotton while utilizing less water.

Building upon the key drivers for change outlined above in Thessaly, this volume delves into the following subchapters:

- **Thessaly's water supply**

- **Thessaly's water consumption**
- **Agricultural efficiency**
- **Transitioning plan**
- **Policies**
- **Early Warning Measures**
- **Recommendations**

The Options at Hand

With the groundwater in the Almyros Aquifer being depleted at a rate of 500 million m^3 each year and saltwater intrusion already having started, it is imperative to remedy the situation sooner rather than later. Whereas there do exist some varieties of grains, legumes and leafy greens that can be cultivated in saline soils, it would greatly hamper Thessaly's agricultural sector to be limited to cultivating just a handful of cultivars. It makes far more sense to replace cultivation of high-water demanding crops with high-value crops now and obviate the risk for a serious salinity problem.

Cumulative Deficit (million m^3)

Year:	1	2	3	4	5	6	7
Water deficit if no interventions are undertaken (in millions of m3)	-500	-1 000	-1 500	-2 000	-2 500	-3 000	-3 500
Water deficit accounting for climate change impact on precipitation (-10% by 2050)	-515	-1 030	-1 545	-2 060	-2 575	-3 090	-3 605

With reservoirs constructed in the mountains, Thessaly would see a gradual increase in the water resources, but this intervention will only alleviate the water deficit marginally. Even if all farmers were to implement reforms to irrigation technology over the next 2 years, saving an estimated 100 million m^3 per year, the impact will be marginal.

Cumulative Deficit (million m^3)

Year:	1	2	3	4	5	6	7
Improvements to irrigation	-465	-930	-1 445	-1 960	-2 475	-2 990	-3505

With modest agricultural reforms, reducing high-water demanding crop cultivation by 50% over 6 years and switching all fodder cultivation as well as replacing high-water demanding crop cultivation with horticultural produce, the tipping point will still be surpassed by 2030.

Cumulative Deficit (million m^3)

Year:	1	2	3	4	5	6	7
Reduction of irrigation of high-water crop cultivation by 50% over 6 years	-408	-836	-1 304	-1 772	-2 240	-2 710	-3225
Reduction of irrigation of cereals (incl. maize) by 50%	-378	-776	-1 214	-1 652	-2 090	-2 530	-3 045
Switching 100% of fodder cultivation from alfalfa to switchgrass / legumes	-301	-623	-984	-1 345	-1 707	-2 070	-2 585
Increasing horticultural production by 100%	-360	-739	-1 159	-1 579	-1 998	-2 420	-2 935

With significant agricultural reforms over 6 years, reducing high-water demanding cultivation by 100% in addition to the other interventions, one would still run a serious risk of saline intrusion as the Aquifer would get depleted by another 2 billion m^3.

Cumulative Deficit (million m^3)

Year:	1	2	3	4	5	6	7
100% reduction of irrigation of high-water crop cultivation (16% per year)	-372	-737	-1 155	-1 573	-1 992	-2 410	-2 828
100% reduction of irrigation of cereals incl. maize	-312	-617	-975	-1 333	-1 692	-2 050	-2 268

Shifting all fodder cultivation from alfalfa to switchgrass / legumes	-235	-463	-745	-1 027	-1 308	-1 590	-1 808
Doubling horticultural production	-293	-580	-920	-1 260	-1 600	-1 940	-2 158

Hence, even if the above reforms are undertaken, the best and most sustainable solution would be to also divert the Achelous River. With this intervention it appears likely to eventually begin recharging the Almyros Aquifer and restore the depleted groundwater levels to a more sustainable level. Note that the calculation is for 300 million m^3, whereas there are indications that up to 600 million m^3 can be diverted.

Cumulative Deficit (million m^3)

Year:	1	2	3	4	5	6	7
Reduction of irrigation of high-water crops by 50% over 6 years	7	20	-20	-60	-100	-140	-58

Thessaly's water supply

While the primary aim of this Master Plan is to mitigate the impact of extreme weather events on Thessaly, it is crucial to analyze the sector's water management, both from a supply and consumption point of view, as irrigation and flooding are inexorably linked. It is an incontrovertible fact that Thessaly's agroindustry can no longer rely on groundwater abstraction. Drastic adjustments are necessary to counteract the declining groundwater tables and prevent the intrusion of saline groundwater in the eastern parts of Thessaly. An environmental and humanitarian disaster is bound to occur if decisive action is not taken.

In order to uphold just a sustainable situation and avert a catastrophe, it would be necessary to, at the very minimum, achieve constant groundwater levels. This would mean that current groundwater abstraction must be reduced by approximately 500 million m^3 per year. In order for this to be realized, sizeable additional water resources are required.

Climate change will likely reduce rainfall with over 30% in Thessaly, while the rise in temperatures will increase the irrigation needs of various crops with over 10% according to Papanastasiou *et al.* (2023). The future may therefore further squeeze the water balance of Thessaly.

Current water source: Boreholes

Groundwater abstraction in Thessaly is done via boreholes scattered across the region. Out of the approximately 33,000 boreholes that have been drilled in Thessaly, 22,000 boreholes have been registered (Figure 1: Location of registered boreholes in Thessaly.). Farmers rely on these boreholes as they need large quantities of water to ensure successful harvests of the crops they are currently cultivating, despite the escalating energy costs caused by having to pump the declining groundwater levels up to the surface.

Controlling abstraction at each of the 33,000 boreholes would be a colossal task and is not practical. Seeing as abstraction poses such a severe threat to the agricultural sector and farmers are dependent on water, alternative means of sourcing irrigation water must be provided.

If no action is taken to address the excessive abstraction of groundwater through the boreholes, farmers will be compelled to drill even deeper for water abstraction. With some boreholes already exceeding 300 meters in depth, they will soon reach saltwater levels. At that critical juncture, the groundwater will get depleted or polluted and a significant number of farmers will suddenly find their farms destroyed and will have no choice but to find other means of supporting themselves.

It is imperative for the government to intervene and avert such a scenario by implementing measures that enable alternative sourcing of irrigation water, as recommended in this Master Plan.

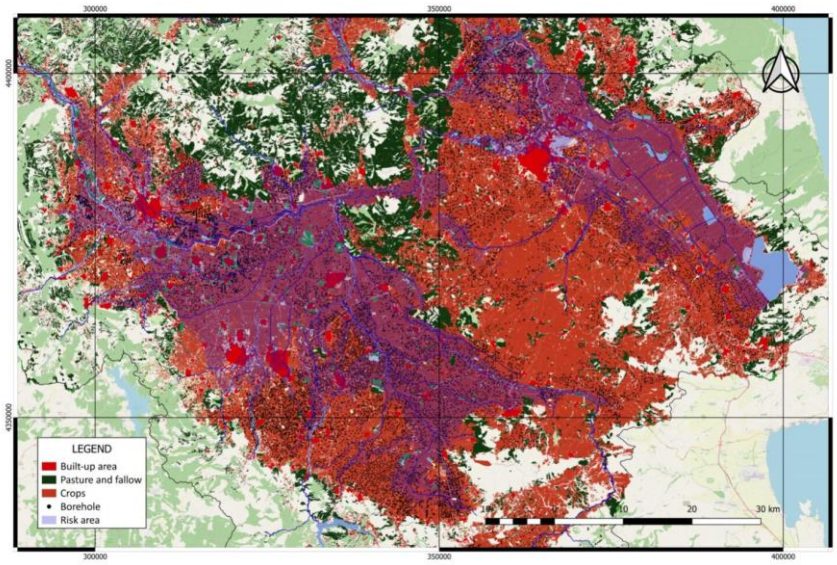

Figure 1: Location of registered boreholes in Thessaly.

The Government has several options at its disposal to reduce groundwater abstraction, which can be implemented while simultaneously providing farmers with viable alternatives.

1. Presently, electricity costs for farmers in Thessaly are subsidized, and a significant portion of this subsidy is being used to subsidize the cost of pumping groundwater. Groundwater abstraction is therefore in essence being subsidized. While withdrawing this subsidy may be an unpopular decision, it is a straightforward measure to encourage farmers to explore alternatives, such as cultivating rainfed

crops or opting for less water-intensive crops. The Government should not only recall the energy subsidy but redirect it toward initiatives that promote sustainable agriculture with reduced groundwater consumption.
2. Impose austere restrictions or a complete ban on groundwater extraction, necessitating robust enforcement capabilities.
3. Introduce fees for groundwater extraction, contingent upon robust enforcement capability

The boreholes in Thessaly currently lack proper metering, making groundwater abstraction difficult to assess and control. In order to achieve effective monitoring of farmers' groundwater abstraction, installing water meters at 33,000 boreholes would be necessary. This, however, would be very cumbersome. It is instead recommended to monitor farmers' electricity usage patterns and bill them for their presumed groundwater abstraction. One can quite easily extrapolate how much is being spent pumping water by comparing farmers' historical expenditures with current ones and deduce the number of cubic meters extracted by contrasting with the pumping elevation in each particular area. This also obviates the need to register all the boreholes. While farmers may try to circumvent this process by powering their water pumps with solar panels or diesel generators, aerial surveillance with drones and simply monitoring the size of farmers' harvests would give an indication as to how much groundwater they are extracting, and one can then bill or fine them accordingly.

One avenue that can be explored is some form of "water pump buyback program" where farmers who have elected to install more innovative, water-saving technologies can trade in their old water pumps or get some kind of subsidies in return.

In summary, the government is urged to immediately cease the indirect promotion of groundwater abstraction through electricity subsidies and to provide alternative water options for Thessalian farmers. Without viable alternatives, the agricultural sector in Thessaly will without a doubt face dire economic repercussions in the very near future.

Additional water basins

One solution to decrease groundwater abstraction involves creating reservoirs like the 'Lake Karla' project. This initiative revitalized a former dried lake ecosystem, aiming to optimize water supply efficiency for agriculture and enhance biodiversity.

It has been determined that Lake Karla now effectively addresses water scarcity concerns, resulting in a twofold increase in crop yield production and corresponding agricultural income in the surrounding region. Furthermore, it plays a crucial role in meeting the water supply requirements of Volos, enhancing the condition of groundwater resources, serving as a natural habitat for biodiversity, and creating new opportunities for recreation and tourism (Panagopoulos, 2020). Consequently, boreholes in the area have become redundant. However, filling sufficient reservoirs to meet current levels of irrigation water for all farmers requires more surface water. This can only be achieved by supplementing water from the Achelous catchment to the Pineios catchment.

Interbasin transfer from Achelous

Interbasin transfer from the adjacent Achelous River Basin to the Pineios River Basin can with considerable certainty alleviate the water scarcity problem that is threatening Thessaly's agricultural sector. While the Pineios River Basin faces a water shortage, the Achelous Basin boasts a water surplus. The feasibility of interbasin water transfer has been studied, and such transfer from the Achelous basin to Thessaly is already occurring, notably from the Plastiras dam, see Figure 2: The Achelous basin with water diversion plans .

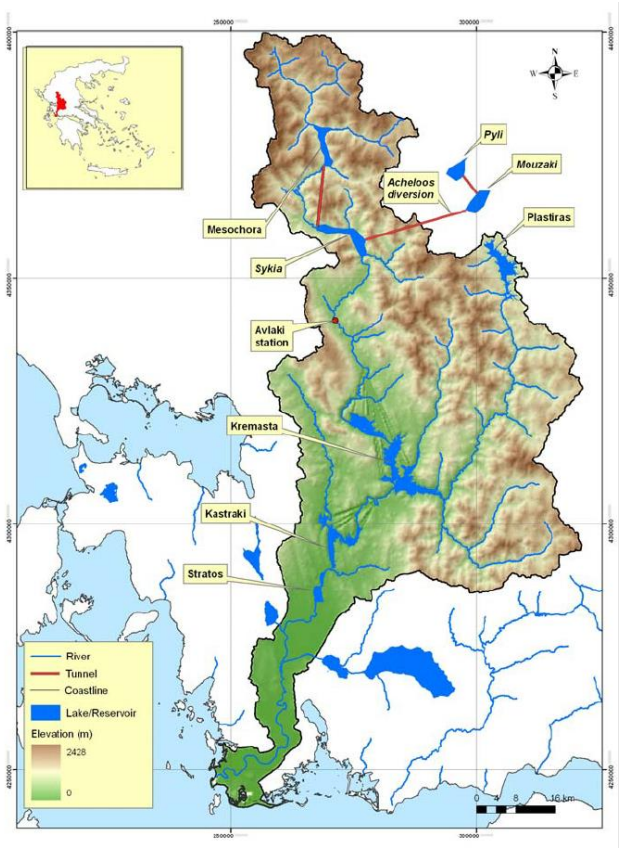

Figure 2: The Achelous basin with water diversion plans (Efstratiadis, 2014)

The oldest dam, Plastiras, is situated on a tributary of Achelous (Tavropos) and diverts the entire runoff of its upstream basin (161 km^2) to the neighboring plain of Thessaly for irrigation and water supply. It capitalizes on a substantial hydraulic head of over 500 meters. Future configurations of the system, involving the interbasin transport of part of the upstream flows of Achelous to Thessaly, have been studied. Some elements of this system have been completed, including the dam and the Mesochora hydropower plant in the upper Achelous course, which have been operationally ready for years. However, the reservoir is currently kept empty, and the project is not operating due to opposition from ecologists and local communities.

The interbasin transfer tunnel is nearing completion, and the construction of the dam at Sykia, the starting point of the tunnel, is in progress with some preliminary works already completed. Environmental concerns revolve around uncertainties regarding the volume of

water that can be diverted from Achelous to Thessaly to ensure the preservation of the delicate ecosystem of the Achelous estuary (Fourniotis, 2012).

Various studies have indicated that this water transfer can be economically, environmentally, and socially sustainable, with annual transfers ranging between 250 and 600 million m^3 of water (Nikolopoulos, 2015). This could present a viable solution to curb the overexploitation of groundwater in Thessaly. However, it would necessitate a significant redesign of the irrigation infrastructure in Thessaly. As of now, the implementation of this interbasin water transfer has not been initiated.

Residents in the Achelous Basin, considered the "owners" of the water, have not received any remuneration or compensatory measures, despite not being directly affected by interbasin water transfer. Instead, all benefits have been directed towards citizens in the Pineios Basin. This discrepancy has resulted in legal issues and disagreements between NGOs and the government. Consequently, despite some progress on the necessary infrastructure, implementation has not been carried out.

The Government is urged to promptly initiate a dialogue with stakeholders in both river basins to reach an agreement on the realization of interbasin water transfer. This is a crucial element for maintaining agriculture as the economic backbone of Thessaly. While the lack of trust among citizens in the state's decisions may present challenges, genuine dialogue and consensus on this issue are essential. Without such agreement, farmers in Thessaly are likely to face adverse consequences.

When replacing groundwater abstraction with the transfer of water from the Achelous to the Pineios Basin, it will be necessary to install distribution networks throughout Thessaly, ideally gravity-driven. Any pre-existing plans for such distribution networks will need to be revised, taking into account areas prone to inundation based on data collected from the two recent medicanes.

Thessaly's water consumption

The agricultural land in Thessaly is hereby categorized into three distinct zones to optimize land management and enhance agricultural productivity:

1. **Surface-Water Irrigated Areas:** This category includes lands efficiently irrigated with surface water, i.e. rivers and streams. These areas benefit from a reliable water source, ensuring optimal conditions for crop cultivation.
2. **Flood-Prone Zones:** Encompassing lands susceptible to inundation, this category addresses the challenges posed by seasonal flooding. Specialized management practices are to be implemented to mitigate the impact of waterlogging and enhance the resilience of crops in these areas. High-value horticultural production should not be developed on land that is prone to inundation.
3. **Higher Altitude Regions with Limited Surface Water Accessibility:** Focused on areas at higher elevations where surface water irrigation is challenging, this category acknowledges the unique difficulties associated with altitude. Strategies such as alternative irrigation methods or water conservation techniques can be explored to address the specific needs of agriculture in these higher-altitude regions.

In regions where surface water irrigation is feasible, the reliance on groundwater can be reduced. In elevated terrains, a cautious approach allows for limited groundwater usage in irrigation, restricted to specified quantities and specific crops. This strategy aims to prevent further depletion of groundwater tables and promote the gradual restoration of groundwater levels.

From an economic perspective, irrigation water needs to be allocated where it yields the highest returns. Implementing a system where farmers pay for water usage ensures that this valuable resource is directed towards areas generating the most revenue. Furthermore, such a pricing mechanism acts as a deterrent against excessive and wasteful water usage.

For this monetary charging system to be efficacious, accurate measurement of water consumption on each farm is essential, with charges corresponding to the volume used. It is imperative that the costs associated with water supply are lower than the assessed value of the water.

The impact of climate change on precipitation and the subsequent implications for irrigation water needs and availability in Thessaly remain uncertain. This uncertainty is underscored by calculations focused on the consequences observed in Trikala, particularly concerning cotton yields (Voloudakis, 2015). A consensus drawn up by the International Plant Protection Convention (IPPC) suggests that the escalation of global temperatures heightens the probability of extreme weather events, characterized by both intensified rainfall and prolonged drought periods. Thessaly, as evidenced by the impact of Storm Daniel (see Figure 3: Rainfall in Thessaly in august and early September 2023.) and Greece has experienced unprecedented bushfires due to droughts.

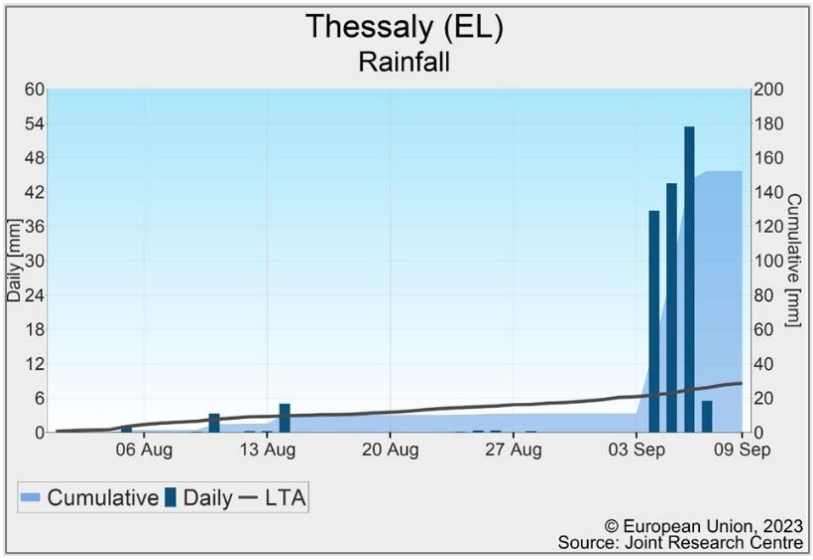

Figure 3: Rainfall in Thessaly in august and early September 2023.

Agricultural practices

Ensuring enduring soil fertility in Thessaly necessitates a proactive approach to minimize erosion, a critical concern that is exacerbated by the escalating intensity of rainfall due to climate change. The vulnerability to erosion is particularly explicit in sloping terrains, a common topographical feature in Thessaly.

The risk of soil erosion is significantly heightened when soil tillage disrupts the soil structure, leaving the surface vulnerable to the impact of intense rainfall. This risk is further compounded when water is allowed to run unchecked, potentially carving gullies and carrying away substantial amounts of soil.

The way to address these challenges is to apply targeted soil management techniques, such as conservation agriculture, wherever feasible. Conservation agriculture promotes better soil compaction and provides protection against the erosive effects of heavy rainfall. By adopting these practices, Thessaly can safeguard its soil fertility in the face of changing climate dynamics, contributing to sustainable and resilient agricultural practices in the region.

Employing minimal tillage techniques, such as direct drilling, offers a strategic approach that leaves most of the soil undisturbed. This practice has dual benefits in protecting the soil from the direct impact of heavy rainfall. Firstly, the retention of crop residues serves as a natural shield, mitigating the direct force of large raindrops on the soil surface. Also, without crop residues, untilled soil tends to be more compact, enhancing its resilience against the impact of large raindrops compared to tilled soil.

When implementing direct drilling or planting in narrow strips, it is advisable to follow contour lines, a practice that enhances water infiltration and diminishes soil erosion. Also, while strong winds threaten soil erosion, the risks can be mitigated by minimizing exposed, bare open soils.

The adoption of soil conservation techniques, as outlined above, in Thessaly comes with the trade-off of losing the potent weed control effects traditionally associated with soil tillage. Recognizing this, farmers must therefore give additional attention to weed management. Herbicides present a risk of environmental consequences, such as water pollution through runoff and soil infiltration, whereas mechanical weed control methods may increase the susceptibility of soil to erosion during heavy rainfall.

Precision farming techniques offer a promising avenue for effective mechanical weed control. Technologies such as RTK-GPS enable precise tractor steering, allowing for meticulous weeding between rows. Advanced weeding machines equipped with specialized cameras, software, and actuators can distinguish between crops and weeds, enabling targeted weed removal within rows. The ideal solution involves the use of weeding machines

that can eliminate all weeds without disturbing the soil, striking a balance between effective weed control and soil conservation in Thessaly's agricultural practices.

It is advised that Thessalian farmers relate to the Hellenic Association of Conservation Agriculture (HACA) as they can provide valuable insights, guidance, and resources on adopting conservation agriculture practices tailored to the specific needs and challenges faced by farmers in Thessaly.

Buffer strips

Constructing buffer strips with vegetation along contour lines represents an effective strategy to relieve significant runoff water. These vegetation strips play a key role by intercepting and slowing down the flow of water, allowing it enough time to get absorbed into the soil. Even if some water does not get absorbed, its reduced speed in the presence of vegetation ensures that, as it continues its downward path under the influence of gravity, it exerts less impact on the soil. This, in turn, results in reduced erosion compared to open fields without buffer strips, highlighting the protective and soil-conserving benefits of this water management approach.

Buffer strips offer an additional advantage by minimizing the runoff of fertilizers and pesticides, thereby reducing surface water pollution. These strips act as a natural filter, capturing and retaining these substances before they reach water bodies. As water infiltrates the soil within the buffer strips, the vegetation present will likely utilize nutrients and pesticides, decreasing the fraction that ultimately seeps into the groundwater. This results in a lower overall environmental load of nutrients and pesticides, showcasing the ecological benefits of incorporating buffer strips into agricultural landscapes.

Moreover, buffer strips contribute to enhanced biodiversity and visual aesthetics in the landscape. Comprising a mix of hedges, trees, grasses, and various herbaceous species, they create a diverse and visually appealing environment.

The optimal width and spacing of buffer strips are contingent on factors such as the slope of the terrain, soil type, and rainfall intensity in the area. Tailoring the design of buffer strips

to these specific conditions ensures their effectiveness in mitigating runoff, promoting biodiversity, and enhancing the overall ecological balance of the landscape.

Irrigation techniques

The integration of precision irrigation technologies holds the potential to significantly enhance crop yields, improve productivity, optimize water use efficiency, and reduce environmental impact. However, recent studies indicate that the adoption of these technologies among farmers in Thessaly has been slow, primarily due to a conservative approach towards investment and risk management.[1]

Farmers in Thessaly tend to be cautious when it comes to embracing new technologies, as they prefer investments that guarantee assured gains. The hesitation to adopt precision irrigation technologies stems from the requirement for substantial initial investments. In order to better understand the factors influencing farmers' decisions, the same team of researchers investigated the intentions of Thessalian farmers regarding the adoption of precision irrigation technologies, specifically in high-water demanding crop production.

While drip irrigation was already widespread, the potential for further precision lay in incorporating fertigation and remote sensing techniques to tailor irrigation practices to the specific needs of plants at different sites and growth stages. The farmers' decision-making process regarding the adoption of these precision technologies was influenced by their perception of the associated investment risks, the expectation of economic benefits, and their awareness of environmental impacts.

Considering the historical trend observed among farmers globally as well as in Thessaly, characterized by a reluctance to swiftly embrace even minor alterations and proven innovations, it is reasonable to expect a considerable degree of hesitancy among them when faced with the prospect of having to undertake significant changes. These changes comprise transitioning to other crops, shifting from traditional arable farming to the

[1] Kakkavou *et al* (2024)

cultivation of orchards and open field horticulture, and exploring the realm of closed horticulture in glass greenhouses.

Agricultural efficiency

Innovation capacity

For farmers in Thessaly to increase their competitiveness within the European market, it is a must for them to increase the quality of their products while at the same time reducing production costs.

As elaborated in Error! Reference source not found., a shift is required where farmers stop perceiving each other as competitors and instead adopt the perspective that is other countries that are their primary competitors.

The crux of reducing production costs lies in optimizing the scale of production. Consequently, if farmers collectively begin to focus on producing identical crops or products, they will harness the economies of scale at a regional level. The heightened production intensity in Thessaly directly correlates with lower unit costs of inputs, enabling larger volumes to be introduced to the international market. This, in turn, is likely to attract more reliable and substantial off-takers, including multinational entities, contributing to a more stable market presence for Thessalian agricultural products.

The chase for quality is an ever-evolving aspect that requires continuous improvement. Innovations within the agricultural sector, in terms of inputs, lighting, irrigation, IoT, drones, harvesting equipment, storage and packaging technology, improved crop varieties, pest management, and transportation, are continuous. It is imperative that farmers stay abreast of these advancements and adeptly incorporate them into their practices so as to increase the quality of their products. Simultaneously, processors must also remain proactive in embracing new production equipment and processes to maintain pace with the evolving landscape.

Numerous studies consistently highlight that farmers and processors that are receptive to adopting innovative technologies consistently gain a competitive edge. This edge often

translates into offering higher quality products at lower costs than their counterparts, positioning them as leaders in the market.[2]

Adopting innovative technologies

The adoption of innovations in agriculture is significantly accelerated when farmers actively share their insights with their neighbors. An open culture that encourages the dissemination of innovations needs to take root in Thessaly. Approaches such as creating study groups need to be widely adopted all over Thessaly, whereby farmers meet regularly to visit each other's operations, engaging in discussions about techniques, innovations, and results. Such collaborative exchange would ensure that best practices are swiftly embraced by the entire farming community and help advance Thessaly's agricultural sector.

Given the risks in agriculture, influenced by unpredictable weather and market fluctuations, farmers tend to have a natural inclination to being risk averse and clinging to traditional practices. However, the global agricultural landscape is one of constant innovation. It is imperative that farmers in Thessaly grasp that failure to innovate will result in their region losing out in the long run. Creating awareness about the relevance of innovation and adopting a cooperative mindset are critical elements in motivating them to proactively engage in adopting new and better practices.

The analysis of complex and dynamic systems within agricultural innovation and technology transfer has yielded remarkable results, generating an unprecedented quantity and quality of food. This has contributed significantly to enhancing global economic and food security (Kalaitzandonakes, 2018). The research underscores that the agricultural innovation system has been consistently evolving, marked by continuous changes in fundamental technical

[2] How farmers innovate has been studied exhaustively by researchers such as Anne van der Ban, based at Wageningen University and Research and Dr. Wais Jan Douwe van der Ploeg. (Leeuwis and van den Ban, 2004 and Van der Ploeg et al. 2002).

discoveries, institutional adjustments, and increasing investments from both the public and private sectors.

The findings conclude the need for societies to adopt a forward-thinking perspective in addressing future challenges, while fostering food security and environmental sustainability. In order to achieve these objectives, it is crucial to establish and sustain long-term approaches that facilitate the entire innovation process—from the conception of original ideas to the development and ultimate utilization of innovations by end-users.

The greenhouse horticulture sector is an excellent example of the adoption of innovation, showcasing improvements across all facets of cultivation, from pest control and water management to the incorporation of new plant varieties and more efficient use of light and heat. Faced with increasing demand for sustainability and the rapid rise in labor and energy costs, the sector has been able to maintain competitiveness thanks to its commitment to continuous innovation. Efficiency, sustainability and cost-effectiveness has been improved remarkably. The fact that the efficiency of artificial lighting in greenhouses has doubled every five years underscores the rapid pace of innovation.

While useful innovations often start with a single goal, solutions in the agricultural sector often end up addressing multiple issues. For instance, more sustainable pest control techniques not only achieve their primary goal but also reduce costs and labor. Similarly, advancements in artificial lighting systems, such as LEDs, not only improve yields but also reduce energy consumption. The swift progress in artificial intelligence (AI) coupled with imaging technology positions the sector for further leaps in innovation, promising cost reduction and improvements in quality and sustainability.

The collaboration between research institutions and farmers in the greenhouse horticulture sector has become so cohesive that when a researcher uncovered in 2020[3] that a longstanding assumption about far-red light[4] not contributing to photosynthesis was incorrect, the sector promptly replaced their LED lighting, embracing systems with a broader spectrum.

[3] Ji et al.

[4] Far-red light refers to photons in the light spectrum that have wavelengths in the 700-750 nanometer range.

Embracing innovation has made the Dutch greenhouse horticulture sector highly competitive; the vast difference in yields achieved in the sector is well-illustrated in Figure 4: National Geographic figure showing tomato yields (2017), which was published in a famous National Geographic article titled "*This Tiny Country Feeds the World: The Netherlands has become an agricultural giant by showing what the future of farming could look like*". It illustrates that Dutch tomato growers achieve 10x higher yields than China even though China is the largest producer in the world, and 34x less water.

In Thessaly, where water scarcity is a serious issue due to depleted groundwater tables, greenhouse horticulture ought to be a very promising avenue to explore, given its notably low water footprint.

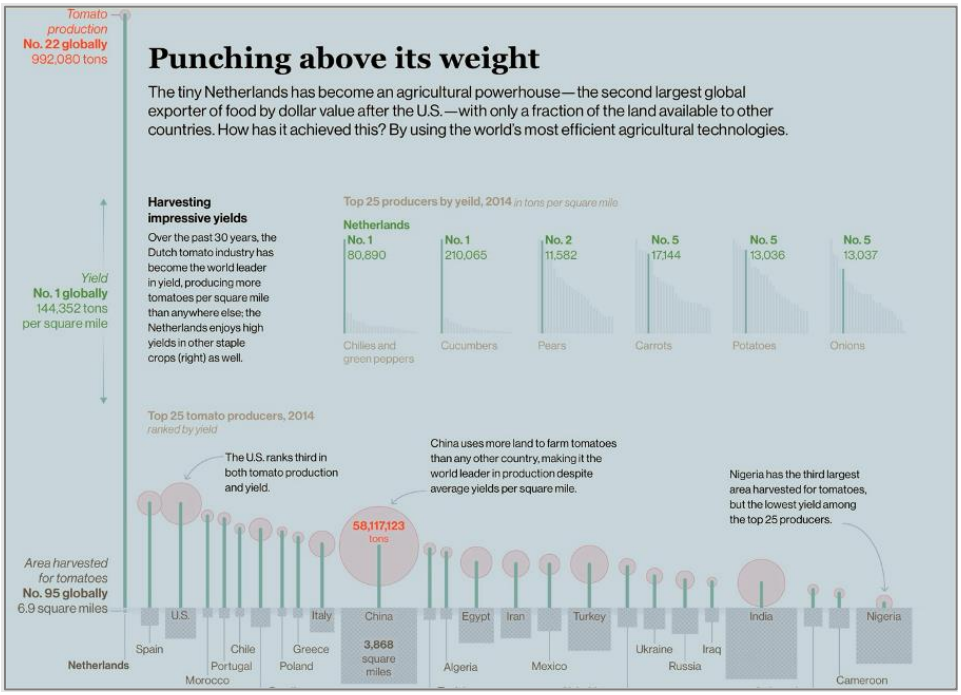

Figure 4: National Geographic figure showing tomato yields (2017)

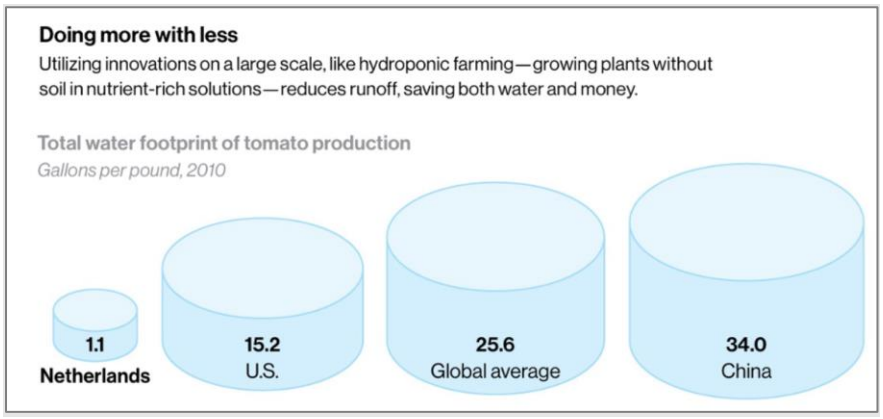

Figure 5: National Geographic showing that innovative technology

Crops and Water Usage

Considering the water scarcity issue in Thessaly, careful consideration must be given to optimizing the utilization of available water resources in the agricultural economy. Figure 6: Global irrigation water values for selected crops , provides insights into the average revenues generated per cubic meter of irrigation water for major global crops, some of which are cultivated in Thessaly. The box plots in the figure show the median and 25th and 75th percentile values.

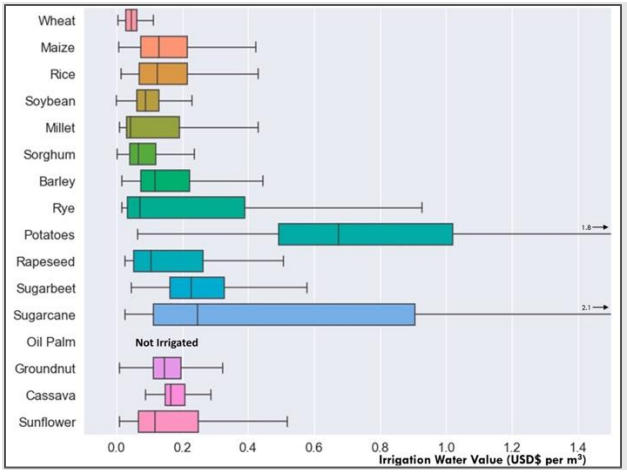

Figure 6: Global irrigation water values for selected crops (D' Odorico, 2020)

Crop varieties currently cultivated in Thessaly, particularly water-intensive crops, pose a challenge in achieving substantial water savings unless there is a reduction in their acreage. The economic viability of continuing cultivation of these crops in Thessaly hinges on the implementation of interbasin water transfer from the Achelous Basin. Relying solely on unsustainable groundwater extraction is simply not feasible, as it will not only lead to salinization but also escalating production costs until farmers are bankrupted. Sustainable water management strategies, such as interbasin transfer, will be necessary in order for Thessaly's agricultural sector to survive in the long term.

Horticulture

Many farmers in Thessaly have already undertaken significant horticultural production, having been forced to shift into this sector due to limited acreage and are finding it a viable means for making a sustainable living. Thessaly is suitable for the cultivation of various vegetables and fruits, while the processing of horticultural products, demonstrated by tomato processing, proves effective in managing large harvest volumes within short timeframes. In order to optimize returns, farmers focus on selling fresh produce, which requires efficient logistics and cold chain management. Leveraging the E75 Motorway provides an excellent transportation route for delivering fresh produce efficiently to markets in Athens and Thessaloniki.

Horticulture should avoid flood-prone areas (Figure 7: Thessaly has large areas without high flooding risks (blue areas)). Favorable regions for development include those located west of the E75 and south of Larissa due to their lower flood risk. This approach ensures secure and sustainable horticultural expansion in Thessaly.

By expanding their horticultural industry, Thessalian farmers will create substantial employment opportunities. The increased need for workers will reach a point where labor shortages necessitate recruiting workers from outside the region. Hosting significant numbers of seasonal migrant workers, particularly from Eastern Europe, notably Ukraine, could contribute to the growth of Thessaly's horticultural sector. This would require

adequate preparations to accommodate them, providing housing, schools, and health services, thereby creating even more jobs in the region.

As evident in Figure 7: Thessaly has large areas without high flooding risks (blue areas) . While there is no specific data for Greece in the table, the extremely low water footprint for tomato production in The Netherlands is a result of its high-tech greenhouse practices. Drawing inspiration from other countries efficiency as shown in the table, Thessaly could potentially increase tomato production 10-fold without increasing its water footprint.

The potential for economic growth in Thessaly becomes apparent when technology is employed to overcome water limitations. Currently, Thessaly has far less of a greenhouse presence than the rest of Greece, with only 150 hectares distributed across regions like Larissa, Trikala, Karditsa, and Magnesia. By comparison, Greece has more than 6,000 hectares under greenhouse cultivation, highlighting that Thessaly is lagging in this sector.

Expanding greenhouse cultivation is important for off-season production for both domestic and export markets. Especially in off-season production, modern technology is vital to minimize energy costs. While products falling under EU labels such as Protected Designation of Origin (PDO) or Protected Geographical Indications (PGI) enjoy some competitive advantages, affordability remains crucial for accessing substantial markets.

Orchard farming is also an important area that needs to be adopted to a much greater extent in Thessaly for several reasons. Beyond yielding much more high-value products such as fruits and nuts, trees serve as a natural shield against soil erosion, enhance the overall landscape quality, and contribute to climate change mitigation by offering shade and cooling through evaporation. Most notably, trees exhibit greater resilience to flooding compared to most cash crops. While many crops struggle to survive extended periods of flooding due to oxygen deprivation, trees, with their deeper-rooted systems, can access oxygen more effectively, enhancing their chances of enduring prolonged flood conditions. There is a slight drawback with orchards, however, that it takes a few years from planting before they begin to yield revenues.

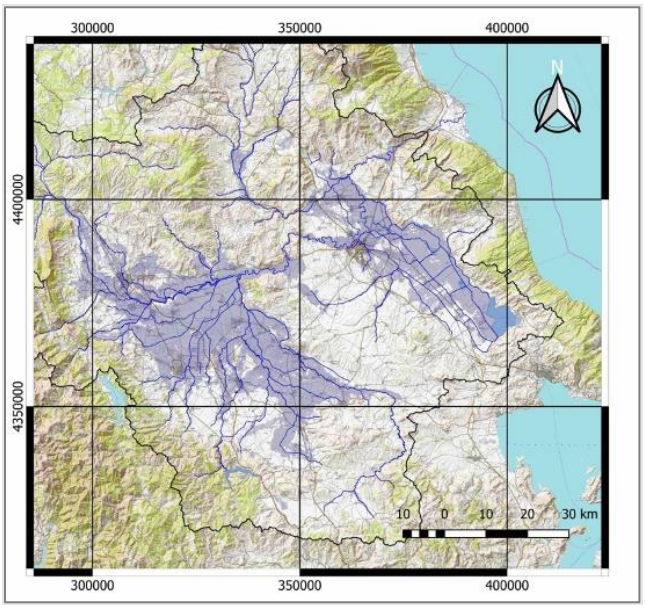

Figure 7: Thessaly has large areas without high flooding risks (blue areas)

Cotton

Thessaly stands as the primary cotton producer in the European Union, cultivating approximately 86,000 hectares, distributed across regions such as Karditsa (40,000 ha), Larissa (25,000 ha), Trikala (10,000 ha), and Magnesia (5,000 ha). The region has received crucial cross-compliance support from the EU, particularly under EU implementing regulation 2017/1185, fostering the popularity of cotton cultivation among Thessalian farmers.

However, the sustainability of cotton production in Thessaly poses significant challenges. Despite consuming over 50% of irrigation water, cotton contributes only 12.8% to the sector's revenues. By contrast, sectors with lower water demand, such as vegetables (22.6%) and fruits (15.6%), make more substantial contributions to Thessaly's economy. Given the scarcity of irrigation water, current practices are utterly unsustainable, leading to declining groundwater tables and escalating pumping costs. Addressing these challenges is imperative for the long-term viability of Thessaly's agricultural sector.

It is important to make sure that cotton is grown sustainably in Thessaly to ensure that it is profitable in the long term. It is important to analyze how other famous cotton-producing areas have dealt with water issues and especially important to analyze what not to do.

The tragedy of the Aral Sea is a stark reminder of what can happen due to unsustainable cotton production. Having once been one of the world's largest lakes, with a volume of 1,090 km^3, the Aral Sea lost 90% of its water (almost 1 trillion m^3) due to indiscriminate irrigation of cotton fields. It became an environmental and humanitarian disaster, that permanently ruined the livelihoods of millions of people, with economic losses estimated at an eye-watering $107 billion (Dukhovniy, 2019). The problem stemmed from excessive extraction of water from the Amu Darya and Syr Darya Rivers, leading to salinization of soils and ultimately disruption of the entire local climate pattern.

Figure 8: The Aral Sea disaster caused by unsustainable cotton cultivation (NASA).

The Nile River Basin has also suffered very adverse impact from excessive water extraction. Egypt, which is famous for its cotton thanks to its fine, long staple fibers, has seen 30-40% of the soils in its Nile Delta become salt-affected due to unsuitable irrigation management.

Also the Murray-Darling Basin, which is one of the most significant agricultural regions in Australia, has experienced very serious salinity problems due to over-extraction of water from its four main rivers. Many farmers' livelihoods were decimated in spite of restoration efforts to mitigate salinity and soil erosion. Just the cost of mitigating dryland salinity alone

has been costing $1 billion AUD per year since 2001 (Australian National Land and Water Resources Audit, 2001).

A fourth example is the Indus River Basin in Pakistan where excessive abstraction of water for cotton cultivation has led to water scarcity and damage to the ecosystem, affecting the livelihoods of millions of people.

An ounce of prevention is often worth a pound of cure, and that holds especially true when it comes to groundwater issues. It is far better to avert a serious salinity problem than to try to mitigate it after-the-fact. Doing so is tantamount to trying to put toothpaste back in the tube.

While the irrigation water value for cotton specifically in Thessaly has not been researched, studies conducted in neighboring Turkey have established a value of 0.15 US $/m3 for cotton (Aydogdu, 2018), (Esetlili, 2022).

Potatoes

Thessaly has surprisingly low potato production despite the high-income potential of this crop. Potatoes offer an astounding 800% higher return on water input other high-water demanding crops. Expanding potato cultivation would therefore enhance revenues and boost Thessaly's economy significantly without affecting the water footprint. (Upadhyaya, 2023).

Effective management skills are crucial for successful potato production. Implementing a crop rotation scheme, such as Year 1 potatoes, Year 2 legumes, Year 3 brassicas, and Year 4 root crops and onions, is essential for maintaining healthy soils. Thessaly's conditions make this rotation feasible. If farmers plant along contour lines to minimize erosion and install drip

irrigation for efficient water use, they will enjoy very good yields and skin quality while needing very little reliance on herbicides and fungicides.[5]

Sugarcane and Miscane

Figure 6: Global irrigation water values for selected crops illustrates that sugarcane has a high water value but is no longer cultivated in Greece. The introduction of sugar beets in the late 19th century led to the discontinuation of sugarcane cultivation in the country, relegating it to tropical regions. Nevertheless, recent developments, including the development of varieties more tolerant to colder climates offer new possibilities (Härter, 2021). Sugarcane can also be crossed with miscanthus to create a chill-tolerant hybrid known as miscane, which is suitable for biomass feedstock and biofuel production. While it is premature to definitively advocate for the introduction of cold-tolerant sugarcane varieties and miscane in Thessaly, further study should be undertaken. Agricultural areas near Lake Karla, in particular, could be suitable, potentially enhancing the agricultural income levels of Thessaly.

Sesame

Oilseed crops such as sesame, once cultivated in Thessaly, hold promise for reintroduction due to its modest water requirements. With favorable pricing and high market demand, sesame presents significant growth potential. Europe faces challenges in achieving self-sufficiency in sesame production, coupled with contamination issues in imports from other parts of the world. This creates a valuable opportunity for Thessaly to address the market gap and establish itself as a reliable source for sesame production, capitalizing on its historical cultivation expertise.

The current subsidy policies in Thessaly, favoring water-intensive crops over less water-demanding crops such as sesame, have inadvertently encouraged Thessalian farmers to overexploit groundwater. This can be damaging to the region's future economic stability. It

[5] Kartakis *et al.* (2023) studied farmers' adoption decision process towards proposed precision agricultural practices in potato production systems in Northern Greece. The results highlighted that the adoption of precision agricultural practices would lead to significantly better economic and environmental outcomes. Their research also concluded that different levels of incentives can be efficiently targeted to encourage the adoption of new practices and secure the sustainability of the agricultural systems.

is strongly recommended to revisit subsidy regimes to align with sustainable water practices. A necessary revision would involve redirecting a substantial acreage currently allocated for high-water demanding crop production towards more water-conserving crops like sesame that can be rainfed.

Achieving food safety and maintaining product quality are pivotal considerations, especially when targeting the European market. Many buyers in Europe demand proof of responsible agricultural practices, often requiring certifications like Global GAP. Adhering to food safety standards involves ensuring limited or no pesticide residues, as well as avoiding contaminants like metals and harmful microbes such as salmonella or E. coli. To meet these stringent requirements, farmers must apply the principles of the Hazard Analysis Critical Control Point (HACCP) system. It is noteworthy that sesame shipments are frequently rejected due to issues such as salmonella contamination and residues of prohibited chemicals like ethylene oxide and aflatoxins, underscoring the importance of stringent quality control measures.

Livestock

The authorities in Thessaly have categorized livestock into 12 distinct types or farming categories, including fish, bees and rabbits among others. This comprehensive inventory is regionally organized in Karditsa, Larissa, Magnisia, and Trikala. In order to evaluate the impact of losses within the Thessaly livestock population, a mortality analysis focused on four key animal categories—sheep & goats, cattle, poultry, and pigs— and showed mortality rates ranging from 3% to 13%.

While these percentages may not be catastrophic for the livestock sector, it is important to recognize that the impact of a severe weather event like Storm Daniel has the potential to disrupt the entire value chain. The mortality analysis underscores that all regions experienced livestock losses primarily attributed to flooding, with drowning being the main cause. Notably, the Karditsa and Larissa regions recorded the most significant losses in sheep & goats, while Larissa reported the highest cattle losses, and Trikala documented the most substantial poultry losses.

Revitalizing the livestock sector is crucial for Thessaly to preserve agricultural and livestock expertise, particularly among farmers, and thereby sustain the livestock economy. The successful rehabilitation of the damaged farming and processing operations relies significantly on the mindset of individuals who have experienced partial or complete loss, and their confidence in resuming operations. During HVA's Fact-Finding Mission, several business owners, including farmers and processing facility proprietors, expressed a disinclination about continuing their operations as two catastrophic floods had impacted them in such a short period of time. Their concerns were primarily that another devastating flood event would occur and wipe out their operations. The issue of water shortage for irrigation did not seem to be at the forefront of their concerns.

The feasibility of continuing business at existing locations depends on the measures that can ensure a secure and protected environment. It underscores the imperative for farmers to comprehend the level of security achievable to prevent floods and safeguard their businesses, livestock, and families. In order to assess this, two key factors need to be evaluated: the current flood risk levels at the locations of their operations and the anticipated anti-flood measures that can be implemented.

Furthermore, strategic decisions should consider long-term water needs and availability during dry periods. Measures include designated areas like controlled flood zones, the application of compensation fees in events where controlled flooding is applied, and their role in water and land management. These considerations will be fundamental when the sector invests in modernization of the livestock sector so as to enhance its competitiveness and resilience under the motto "*build back better*."

The significant livestock losses in Thessaly as a result of Storm Daniel were attributed to the short notice farmers received (just 2 to 3 hours) that severe flooding was imminent and necessitated evacuation. For efficient livestock evacuation, a time window of at least 48 hours is necessary. It is important to note also that the 48-hour time frame is effective only when accompanied by a well-prepared livestock evacuation plan. Such a plan must outline specific protocols for different animal types, enabling their evacuation to higher ground, ensuring access to feed, and implementing veterinary procedures.

Water usage in the livestock sector

A primary recommendation is that water use for irrigation of feedstocks be reduced, as this constitutes a significant portion of water usage in the livestock sector. Additional recommendations to reduce water consumption in the livestock sector include:

- **Water-efficient livestock watering systems:** Water management would be optimized by implementing efficient watering systems, such as drip or trickle systems, significantly reducing water wastage.
- **Water recycling and reuse:** Water conservation measures need to be implemented by introducing systems designed to capture and treat wastewater generated by livestock operations for subsequent reuse in non-potable applications, such as cleaning or irrigation.
- **Strategic water storage:** On-farm water storage systems, such as ponds or tanks, need to be incorporated so as to facilitate controlled utilization of water, particularly during dry periods. The collection and storage of rainwater will further enhance the resilience of the water supply, offering an additional water source during the rainy season and mitigating the need for excessive reliance on groundwater resources.
- **Grazing management:** Rotational grazing needs to be implemented so as to maintain healthier pastures, reducing the need for extra watering during dry periods.
- **Community awareness and education:** Awareness needs to be increased among both farmers and the community that water conservation and sustainable practices are crucial. Educational programs need to implemented advocating responsible water management and fostering the adoption of technologies to optimize water usage.

Modernization initiatives should cater to businesses of different sizes, aiming to empower, for example, an average-sized family to earn a fair income from their agricultural endeavours. Simultaneously, it is advised that funds within this framework be allocated to facilitate the relocation of farms situated in flood-prone areas.

Alfalfa and fodder crops

Ensuring an ample feedstock supply is pivotal for Thessaly's livestock sector. While the production of key fodder crops like alfalfa and maize has had high yields thanks to irrigation,

the increasing costs necessitate exploring alternative strategies. One option is cultivating fodder in Thessaly that can be rainfed, such as switchgrass. That would reduce the livestock sector's dependence on irrigation. Another solution is to source feed from other regions of Greece where water is not as scarce. While such a solution may increase feed costs, that would easily be counteracted by cultivating other crops in place of alfalfa.

Cooperative approach

Despite having 1,056 collective bodies registered in the National Register of Agricultural Cooperatives, potentially the highest number among all European Union member countries, these cooperatives are believed to generate the lowest value per cooperative. Additionally, their financial challenges are underscored by overdue debts, which, a few years ago, reached approximately 2.5 billion euros.

When revitalizing agricultural operations, the stakeholders will need to reconstruct animal shelters, upgrade production facilities, enhance infrastructure, and replace or repair equipment and machinery. Farmers and processors ought to then collaborate during the procurement process so as to make more well-informed decisions and strengthen their negotiating power with suppliers.

The most effective way to coordinate such collaborative effort is through established cooperatives or farmer groups and is a proven way to economize on expenses. It is advised that regional authorities support such initiatives through the provision of information platforms.

Moreover, the collective procurement strategy should also include architectural designs, such as electrical plans, water supply, and drainage systems, as well as fortification measures to counteract floods, such as barriers or embankments, so that the designs are "flood-resistant".

The synopsis below outlines key considerations for stakeholders on how to go about leveraging their combined purchasing power in an optimal fashion:

- **Consolidate Resources:** When modernizing operations, the members of a cooperative can share the services of consultants and architects so that all can take advantage of their know-how and ascertain their needs.
- **Preparation:** Before inviting suppliers, the cooperative should have ascertained the quantities they will need, quality and have a good idea of ballpark pricing and terms, including delivery schedules and post-sales service.
- **Skilled Spokesperson:** It is important to act as a unified entity with a spokesperson with negotiation skills.
- **Tendering:** Rather than go to individual suppliers and request offers, these should be invited to present competing offers to the cooperative, much the way tenders are issued, so rather than listen to sales arguments, the cooperative can have suppliers "battle it out" and press prices and terms so that the stakeholders get the volume discounts and value for their money.
- **Utilizing Existing Cooperatives:** Existing agricultural cooperatives provide valuable platforms for coordinating collective procurement efforts. These cooperatives typically possess established networks, resources, and expertise that facilitate joint purchasing initiatives among farmers.
- **Facilitation by Relevant Authorities:** Relevant authorities can streamline organizational processes by leveraging recommended information platforms and offering guidance and support for collective procurement initiatives. Their role may extend to coordinating technical assistance, sharing best practices through extension services, and facilitating collaboration among stakeholders.

By applying these points, stakeholders will optimize the efficiency of rehabilitation efforts while simultaneously fostering the exchange and promotion of sustainable practices within their farming and processing communities.

An initial budget of 75 million euros has been earmarked for the creation of an agricultural contracting cooperative/company. The source of funding, whether from public or private channels, is yet to be determined.

Transition plan

Analysis of the data underscores the need for Thessaly to reconsider its approach to water supply and utilization in agriculture. This section presents and analyzes the potential solutions based on a simplified methodology, with the aim of producing a recommended scenario for water management in Thessaly. Note that this methodology does not aspire to deliver a precise and detailed analysis. The primary objective is to emphasize sustainable solutions that not only address Thessaly's water-related challenges but also offer opportunities for farmers to forge a sustainable and economically thriving future. The focus is on promoting environmentally responsible practices that enable the region to navigate water concerns in a sustainable manner.

Achieving this transformation involves expanding horticultural acreage while decreasing the irrigated acreage being used for non-horticultural purposes. Notably, livestock fodder production, which currently consumes a substantial amount of water, needs to be revamped. A transition must be made to alternative fodder crops, replacing alfalfa with a mix of switchgrass and legumes that require minimal irrigation.

In order to address water consumption effectively, one of the main strategies will be to gradually discontinue irrigation of arable crops in Thessaly over a span of 6 years while simultaneously doubling the horticultural acreage within the same timeframe, as illustrated in Figure 9: Suggested irrigated acreage in Thessaly. This is based on the 2022 acreage figures of the Ministry of Agriculture for Thessaly and on the water requirements (Hazigiannakis, 2020). This strategic shift will decrease irrigation water usage by over 50%, contributing to a far more sustainable water management system. Furthermore, this approach will provide a significant economic boost for the agricultural sector with a projected growth rate exceeding 25%, as depicted in Figure 10: Effect of irrigated acreage in Thessaly on water demand and on economy. A gradual change to subsidies, such as focusing on sustainability measures, will encourage farmers to explore alternative crops.

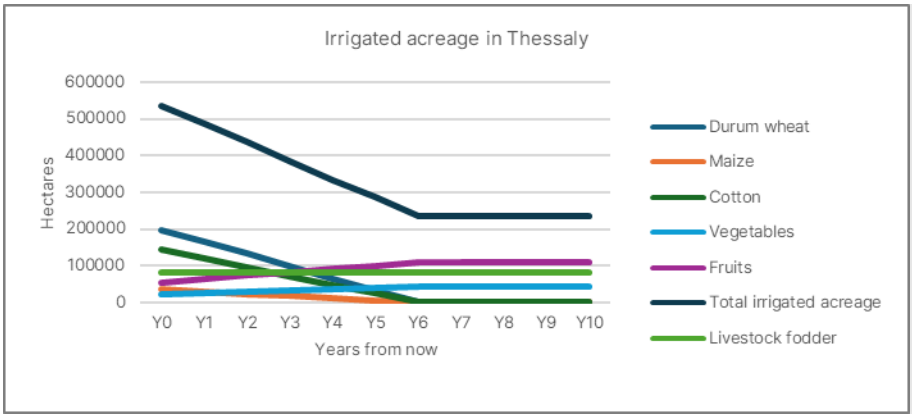

Figure 9: Suggested irrigated acreage in Thessaly

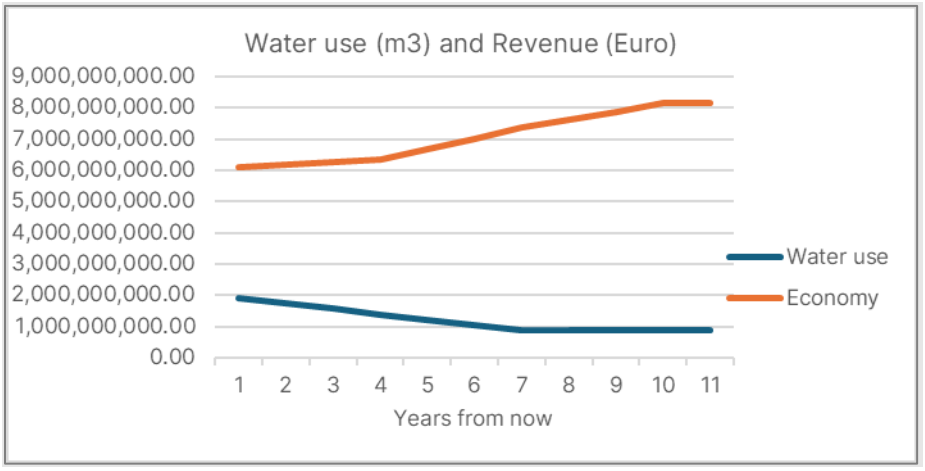

Figure 10: Effect of irrigated acreage in Thessaly on water demand and on economy.

Another important intervention to enhance resilience in flood-prone areas is the replacing of highly perishable crops with orchards. This will protect the areas against inundation impacts seeing as trees have much deeper root systems.

The shift towards horticulture requires investments to convert farms into vegetable and fruit production hubs. Financial returns from the investments in vegetable production will be immediate whereas returns from fruit investments will require approximately four years, until the first harvest. This proposed scheme for new horticultural production entails an annual investment of nearly 2 billion euros, i.e., almost 12 billion euros over the 6-year transition

period for the private sector. Government support to make this turn-around can ease and accelerate this transition.

Despite the substantial investment, these crops are anticipated to generate 1.5 billion euros of additional revenue each year. This means a relatively swift payback period of approximately 8 years.

Modernizing feta cheese production facilities at approximately 800 farms that are cultivating fodder and replacing these with switchgrass and legumes will require an investment of roughly 2 million euros per farm. However, such investment promises significant economic growth, making the investment a viable and strategically wise move for the agricultural sector.

In regions immune to flooding, the horticultural acreage can and should be doubled within 6 years. Irrigation of other agricultural crops in these areas should simultaneously be reduced gradually over the same 6-year period until it is phased out completely.

In regions sensitive to flooding, the recommended strategy is to transition as much acreage as possible to perennial crops, particularly orchards, over a period of 6 years. This will have the added benefit of stimulating both job creation and income. In order to mitigate the impact of inundations, packhouses and other valuable assets for the orchards need to be constructed in the locations that have been marked as secure from flooding.

Within this 6-year timeframe, the consequences of any potential inundations would be less damaging than those experienced in flood events such as the one precipitated by Storm Daniel, although there may still be temporary negative effects on agricultural production, necessitating evacuations and the safeguarding of valuable assets. In these targeted areas, the irrigation of annual crops will gradually be phased out over the same 6-year period.

The need to change cropping patterns

If agricultural practices in Thessaly are not reformed, the inevitable consequences will be dire. Even though the Almyros aquifer gets replenished with rainwater, abstraction is more than twice the recharge rate, leading to an alarming decline in groundwater levels. The

intrusion of seawater into the groundwater is already adversely affecting water quality. Seeing as Thessaly does not have a uniform groundwater table, some farmers can access groundwater easily but others are being forced to pump water from a depth of several hundred meters. The table is, however, falling at a rate of 5 meters per year, resulting in rapidly increasing pumping costs. It is also clear that farmers are consuming far more water now than 15 years ago, indicating that agriculture has been intensifying.

The declining groundwater tables necessitate pumping water from greater depths, increasing energy needs. The groundwater table is diminishing at a rate of 5 meters annually (Paleodogos, 2013). Pumping is already a very costly affair and the 5 additional meters each year means that energy consumption cost increases every year. The substantial increase in costs will intensify the irrigation of specific lands, leading to diminished yields and, ultimately, prompting farmers to consider discontinuing their farming activities.

Further research needs to be conducted to investigate the repercussions of escalating pumping expenses leading to the abandonment of irrigation. If, due to the increasing pumping costs and deteriorating groundwater quality, 5% of the irrigated land ceases to be irrigated, Thessaly could face substantial economic decline, as depicted in Figure 11: Economic effect of no change - 5% reduction. Considering alternative land use options, aside from rain-fed agriculture, some land could be repurposed for solar parks. Converting irrigated land into photovoltaic (PV) solar parks is a financially viable alternative, albeit with high initial investments (Sargentis, et al., 2021). While this change may compromise food security, it would enhance energy security in Greece. Growing energy crops for electricity production, however, may not significantly benefit farmers' incomes.

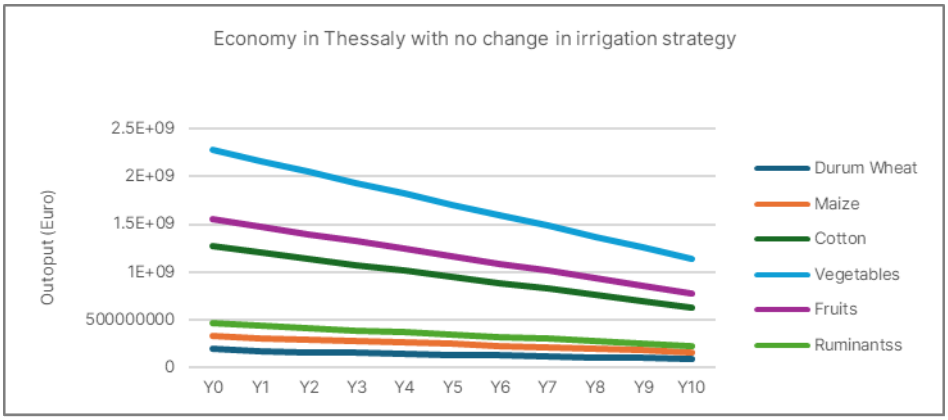

Figure 11: Economic effect of no change - 5% reduction due to pumping

Achelous diversion

The transfer of water from the Achelous Basin to the Pineios Basin to ensure the sustainable development of Thessaly is, from a water management perspective, a crucial consideration. Starting the water transfer process will enable replenishing groundwater levels. Any surplus surface water earmarked for irrigation holds the potential for diverse applications. If a water transfer of 300 million m^3 is dedicated to developing additional horticultural in Thessaly, evenly distributed between vegetables and fruits, the region's economy could experience an augmented boost of over 3 billion Euros annually, as illustrated in Figure 12: Water transfer from Achelous from year 4 will increase acreage . Simultaneously, this approach allows for the moderation of groundwater abstraction, as demonstrated in Figure 13: Water transfer from Achelous used for horticulture effect on economy, steering towards sustainable levels of water use. However, further comprehensive studies are imperative to precisely determine sustainable abstraction levels and the restoration of the aquifer to historical levels.

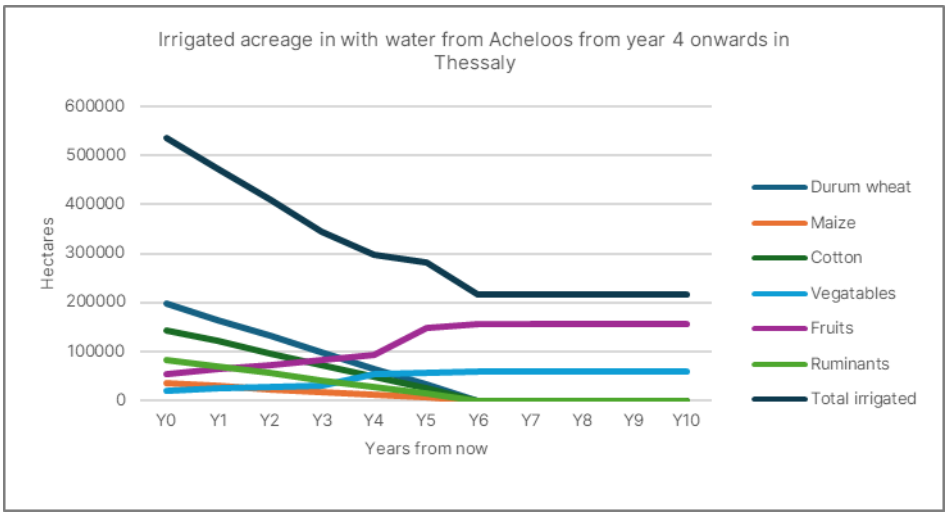

Figure 12: Water transfer from Achelous from year 4 will increase acreage

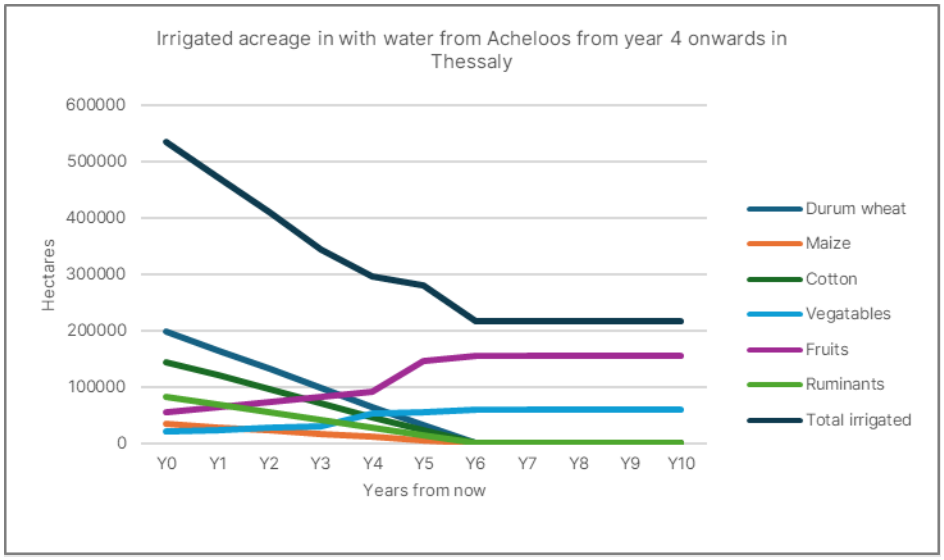

Figure 13: Water transfer from Achelous used for horticulture effect on economy

The future for livestock

In order to sustain the current production levels of sheep, cattle, and goats, it will be necessary to maintain the existing quantities of fodder supply for these animals. As Thessaly anticipates a reduction in irrigation for fodder production over the next six years, exploring alternatives becomes crucial. One viable option is the cultivation of switchgrass with legumes, proven to be effective. Research conducted in Palamas indicates that substantial quantities of high-quality hay can be produced without irrigation, particularly in areas with shallow groundwater (Giannoulis K. G., 2013). These locations, like Palamas, with shallow groundwater, are optimal for producing switchgrass hay to meet local needs in Thessaly.

For regions with deeper groundwater, such as Velestino, switchgrass yields are modest without irrigation. However, with a moderate irrigation of 200 mm, satisfactory yields can be achieved (Giannoulis, Bartzialis, Skoufogianni, Gintsioudis, & Danalatos, 2022). The combination of switchgrass and legumes under these conditions not only results in good yields but also produces high-quality fodder, as illustrated in Figure 14: Economy when irrigation water use is halved . This approach provides a sustainable solution to maintain fodder production even with reduced irrigation in Thessaly.

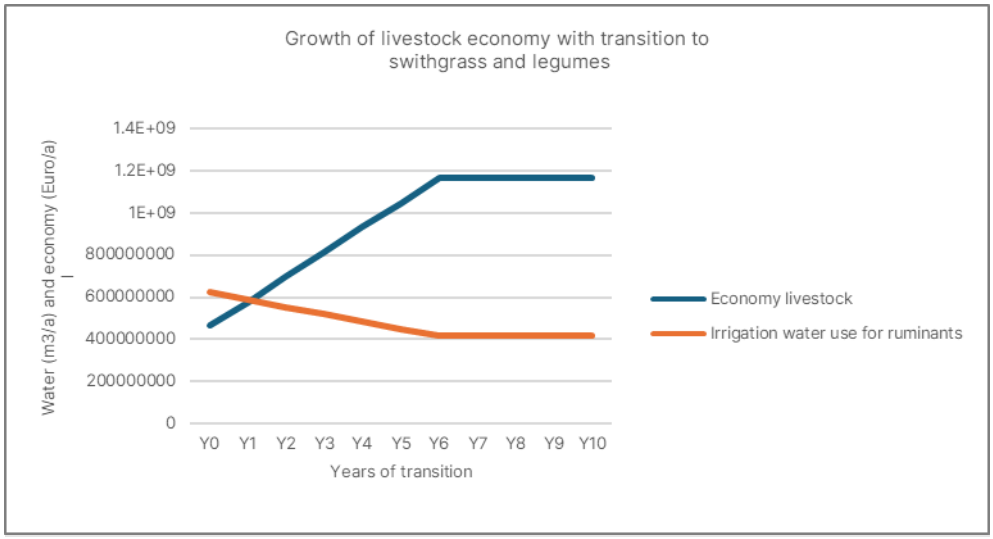

Figure 14: Economy when irrigation water use is halved + fodder transition

Early Warning Measures

The sooner an agreement on rehabilitation strategies within the sector is established, the quicker relevant stakeholders and authorities are able to implement interventions to modernise and bolster the competitiveness and resilience of the sector. However, kickstarting the modernization process demands a significant investment push. It is crucial for stakeholders, being mainly the local farmers in Thessaly, to have confidence that their investments are secure and not susceptible to bankruptcy, particularly in the face of potential future disasters such as floods.

While the recommended measures outlined in the Water Management Plan can reduce the probability of recurrent floods, it is unlikely to eliminate the risk across all areas. Recognizing and comprehending high-risk zones and their respective risk levels is crucial for stakeholders in the sector. This information becomes a pivotal factor in the decision-making process regarding investments geared towards the expansion and modernization of the sector.

It is in the interest for the sector to promptly and thoroughly comprehend the measures and conditions entailed in implementing the Water Management Plan. With clarity on these aspects, relevant stakeholders can ascertain the necessity of adopting independent measures to safeguard their businesses, such as constructing protective walls or contemplating relocation. Moreover, they can evaluate the feasibility of financial commitments for modernization.

It must be noted that the proposed measures primarily focus on reducing the vulnerabilities of smallholder farming operations. Simultaneously, the available funds aim to catalyse comprehensive growth and modernization across the entire sector.

In order to facilitate the rehabilitation process, the relevant authorities ought to create an information platform[6]. This platform will function as a centralized space where authorities can share and publish information, promoting communication with sector stakeholders on various aspects related to flood prevention and rehabilitation. This may include formulating

[6] Digital access to this platform should be facilitated, and individuals should also be able to access it through a helpdesk organised by the relevant authority.

key strategies for assessing risk areas, providing updates on compensating for losses, and reporting progress on sector rehabilitation.

Livestock evacuation planning

Regarding the evacuation of livestock in preparation for potential disasters like floods and fires, it is crucial for stakeholders – livestock owners, authorities, cooperatives - to have an evacuation plan agreed upon. In an emergency preparedness plan some elementary decisions must be taken related to the practicality and economic feasibility of evacuating within the timeframe provided by the early warning system, considering both the quantity and value of the livestock.

Initially, it is imperative to ensure that high-value assets like livestock housing, machinery, and implements are not situated in flood-prone areas. Nevertheless, if these assets are indeed placed in such areas, including livestock, having an emergency preparedness plan becomes most essential.

A region-specific evaluation should be undertaken, examining the situation for each type of animal and identifying safe areas. For instance, horses may have a higher success rate in evacuation due to their higher value, lower overall numbers, and a larger number of individual owners when compared to, for example, poultry. However, the situation is more complicated with cattle, sheep, and goats, whose loss may have a higher impact on the value chain because the losses take longer to recover.

Enhancing the effectiveness of the Early Warning System involves the progressive issuance of warnings at various time intervals preceding the flood, as discussed in Error! Reference source not found.. Each message serves to prompt specific actions in accordance with established protocols, thereby optimizing the impact of the final action, should it be executed.

- **Step 1 - Flood alert:** At this point, livestock owners should activate the crisis plan in accordance to the crisis plan and collaboration with their farming organizations and

authorities. This involves organizing the readiness of logistics of vehicles and trailers, including fuel, drivers, and reinforcement for handling the livestock and feed.

- **Step 2 - Flood warning:** By this time farmers should evacuate their livestock given the complexity of managing the logistics of transportation.
- **Step 3 - Severe flood warning:** By this time flooding is imminent and livestock, feed, personnel etc. should have already been evacuated.

Note: The primary responsibility for ensuring the welfare of the animals rests with the owner (livestock farmer). Therefore, it is the livestock farmer, either independently or in cooperation with their sector organization, who must proactively take steps to evacuate their livestock in accordance to prepared plans. By recognizing the potential threat of an approaching flood and promptly relocating the animals to safety, the animal keeper complies with their general duty of care.

The responsibilities of the Water Management Organization concerning evacuation encompass the examination of various aspects, including specific considerations for livestock:

- **Types of livestock for evacuation:** Classify the types of livestock suitable for evacuation, considering practical constraints and associated costs.
- **Designated safe zones:** Assign secure zones customized for each type of animal, considering factors like the availability of shelter and access to feed markets.
- **Logistics planning:** Consider the required logistics for transportation, taking into consideration factors such as the type of animals, distance to be covered, and the availability of suitable vehicles.
- **Economic feasibility:** Consider the economic feasibility of potential livestock losses and evacuation costs, recognizing their impact on the overall value chain.
- **Organization and coordination:** Implement, test and maintain efficient channels of communication and coordination among pertinent authorities, farmers, and other stakeholders to ensure a well-organized evacuation process.
- **Veterinary capacities and protocols:** Assess the existing veterinary capacities and develop essential protocols to prevent and control diseases, thereby minimizing the risk of outbreaks during the evacuation process.

- **Farming community engagement:** Engage and educate local communities in the evacuation process, promoting collaboration and awareness through information campaigns.
- **Financing:** Ensure that the funding mechanisms[7] align with the protocols and incentives for evacuation.

Analysing current livestock mortality data during the Daniel storm per region reveals a significant concentration of high-value livestock, including cattle, sheep, goats, and pigs, in Larissa and Karditsa. In contrast, Trikala experiences higher poultry mortality. These data provide a foundation for developing evacuation plans, taking into consideration factors such as distances (and associated costs), to determine the feasibility of evacuating livestock from these areas. This information, coupled with farmers' understanding of the risk levels of their farming location both before and after implementing flood protection measures, is crucial. It empowers farmers to make informed decisions about taking independent measures, such as constructing dikes or walls around their premises, to protect against flooding.

The recommended Water Management Organization is advised to take on the responsibility of designing and executing plans for the evacuation of livestock, equipment, and other valuable assets in anticipation of potential disasters like floods and fires. This oversight should prioritize the practicality and economic feasibility of evacuating within the timeframe provided by the early warning system, factoring in both quantities and values. In the event of an emergency, a tailored evaluation must be present and well understood by all the stakeholders. This evaluation should encompass assessing the risks and affected areas, considering the circumstances for each type of farm and other entities in the value chains, and identifying secure areas.

The oversight must comply to EU regulations on animal welfare. Referencing to an exemplary Emergency Farm Plan template (County, 2022) provides a framework highlighting key considerations. This template can serve as a guide to assist in preparing an evacuation plan for Thessaly or the specific regions individually.

[7] Rehabilitation fund should not be mistaken for expenses designated to compensate the loss of animals due to drowning resulting from the storm Daniel in September 2023.

Policies

1. **Increase the economy of scale by promoting family farms.**

In a national agriculture and livestock development program focused on promoting family-based enterprises and generating a fair income, several key economic attention points should be considered to ensure the success and sustainability of such initiatives:

- **Access to capital:** Family-based enterprises often face challenges in accessing capital for investment and expansion. Therefore, the development program should prioritize providing financial assistance, such as low-interest loans, grants, and subsidies, to help these enterprises acquire necessary resources, invest in modern technologies, and expand their operations.
- **Market access and market information**: Ensuring market access and providing accurate market information is crucial for family-based enterprises to make informed decisions about production, pricing, and marketing strategies. The development program should facilitate access to markets through infrastructure development, transportation networks, and market linkages. Additionally, providing training and support in market analysis and market trends will empower entrepreneurs to identify and exploit opportunities for growth and profitability.
- **Capacity building and skills Development:** Family-based enterprises require the necessary skills and knowledge to effectively manage and operate their businesses. The development program should invest in capacity building initiatives, including training programs, workshops, and technical assistance, to enhance the entrepreneurial and managerial capabilities of farmers and livestock keepers. Topics such as financial management, business planning, agricultural practices, and value-added processing should be prioritized to improve productivity and competitiveness.
- **Technology adoption and innovation:** Embracing technological advancements and innovation is essential for enhancing the productivity, efficiency, and sustainability of family-based enterprises. The development program should promote the adoption of modern agricultural practices, mechanization, precision farming techniques, and digital technologies to optimize resource use, reduce production costs, and increase yields. Furthermore, fostering research and development initiatives to address specific challenges faced by family-based enterprises will stimulate innovation and drive economic growth in the agriculture and livestock sectors.

- **Value chain integration:** Integrating family-based enterprises into broader value chains can create opportunities for value addition, diversification, and market differentiation. The development program should facilitate linkages between farmers, processors, distributors, retailers, and consumers to streamline production, distribution, and marketing processes. Strengthening value chain partnerships, promoting collaboration, and encouraging vertical integration will enhance the competitiveness and resilience of family-based enterprises in domestic and international markets.
- **Policy support and regulatory frameworks:** Enabling policy environments and supportive regulatory frameworks are essential for creating an enabling environment conducive to the growth and development of family-based enterprises. The development program should advocate for policies that prioritize smallholder farmers and livestock keepers, promote inclusive growth, protect land rights, ensure access to natural resources, and facilitate equitable market participation. Additionally, streamlining administrative procedures, reducing bureaucratic barriers, and providing incentives for entrepreneurship will foster a conducive business environment for family-based enterprises to thrive.

By addressing these economic attention points within a comprehensive agriculture and livestock development program, policymakers and stakeholders can empower family-based enterprises to achieve sustainable livelihoods, economic prosperity, and social well-being for rural communities.

2. **Enhance the pedigree of animals through improved breeding practices.**

In Greece, several indigenous breeds of sheep and goats thrive in diverse climatic and geographical conditions, contributing significantly to the country's livestock industry. Key breeds include the Karagouniko and Chios sheep, along with the Skopelos and Katsika Fthiotidas goats. These breeds are valued for their adaptability, productivity, and unique characteristics such as high milk production, quality meat, and resilience to harsh environments. In order to further develop these breeds and enhance their contributions to the Greek livestock sector, the following recommendations are advised:

- Implementing selective breeding programs aimed at enhancing desirable traits such as milk production, meat quality, and disease resistance can improve the overall performance and productivity of indigenous breeds. Collaboration with research institutions and breeding associations can facilitate the implementation of effective breeding strategies.
- Promoting the marketability of products derived from indigenous breeds, such as high-quality cheeses from Chios sheep milk or gourmet meat from Karagouniko sheep, can create economic opportunities for farmers and stimulate demand for these breeds. Establishing market linkages and promoting value-added products can enhance the profitability of livestock farming.
- Providing education and training to farmers on best practices in breed management, animal husbandry, and sustainable farming techniques is essential for optimizing the potential of indigenous breeds. Extension programs, workshops, and knowledge-sharing initiatives can empower farmers with the skills and knowledge needed to effectively raise and manage these breeds.
- Investing in research and innovation to address challenges related to breed health, nutrition, and management can contribute to the continued improvement and development of indigenous breeds. Research initiatives focused on enhancing productivity, resilience, and sustainability can provide valuable insights and inform breeding and management practices.
- Efforts should be made to conserve and preserve indigenous breeds to maintain genetic diversity and safeguard cultural heritage. Establishing breed registries and implementing conservation programs can help protect these breeds from genetic erosion and ensure their long-term viability.

3. Education requirements for modernizing agriculture and livestock farming

Considering the developing the landscape of agriculture and livestock farming, it is imperative to address the educational needs of farmers and farm workers. As the sector aims to transit towards modernized farming practices, education emerges as a critical factor in ensuring the sustainability and efficiency of agricultural operations.

According to the latest available data from Eurostat (referring to the year 2020), only 0.7% of farm heads in Greece had complete agricultural training – in the sense that after compulsory education they attended a training program of at least 2 years and studied in higher education in a subject related to the primary sector. This is the lowest percentage found in the European Union, with Greece sharing this last, not at all honorable, position with Romania. One would reasonably argue that farmers today are quite a bit more educated and skilled compared to the picture we had in the mid-90s and shortly after, the era of the great farm movements. Indeed, compared to 2010 the percentage of farm heads with full training has almost doubled (it was only 0.32%), but it still remains hopelessly low. At EU level it is also very low, only 1 in 10, but there are also EU member countries. where the corresponding percentages are very high, such as the Netherlands (62.8%) and France (38.4%). In the other Mediterranean countries the percentage is low, but many times higher than that of Greece (6.78% in Italy, 4.08% in Spain). 72.30% of the heads of agricultural holdings in Greece only have practical experience, useful no doubt, but not capable and sufficient for the exercise of agricultural activity, as it develops today.

In the process of modernizing agriculture and livestock farming, it is essential to recognize the educational prerequisites for effective management and operation. Medium to large farm owners, who serve as the backbone of the sector, necessitate a minimum of secondary educational attainment. This educational baseline equips farmers with the necessary comprehension of economic principles and facilitates informed decision-making in their agricultural endeavours.

Moreover, beyond the ownership level, farm operators and technicians play pivotal roles in executing mechanical and automated operations within farming environments. Hence, there is a growing demand for practical education that empowers individuals to navigate the complexities of modern agricultural machinery and automated systems effectively.

In addition to more generic topics, specialised knowledge domains are to be included for optimising farming practices and ensuring productivity. These areas encompass but are not limited to:

- **Nutrients:** Understanding the nutritional requirements of crops and livestock is crucial for maintaining optimal health and maximizing yield.

- **Breeding:** Knowledge of breeding techniques and genetics enables farmers to selectively enhance desirable traits in their livestock (and crops).
- **Mechanization and automation:** Proficiency in operating and maintaining mechanized and automated equipment is essential for streamlining farm operations and enhancing efficiency.
- **Crop protection**: Familiarity with crop protection methods and technologies aids in safeguarding crops against pests, diseases, and adverse environmental conditions.
- **Food Safety:** Adherence to food safety standards is imperative for ensuring the quality and integrity of agricultural products throughout the supply chain.

Given the multifaceted educational requirements inherent in modernising agriculture and livestock farming, the following initiatives may be reviewed:

- **Review of educational programmes:** Collaborate with educational institutions to design and implement specialized programs tailored to the needs of the agricultural sector.
- **Training and capacity building:** Facilitate training sessions and workshops to enhance the technical competencies of farmers, farm operators, and technicians.
- **Knowledge dissemination:** Establish platforms for knowledge exchange and dissemination, fostering collaboration among stakeholders and facilitating access to relevant information and resources.
- **Incentivisation of education:** Implement incentives and support mechanisms to encourage individuals to pursue education and training in agricultural-related disciplines.
- Organise an integrated approach between government authorities (MoA), farming organizations and universities in conducting studies and developing policies related to education and modernization in agriculture and livestock farming including organising independent agriculture extension services.

In conclusion, education serves as a cornerstone for the modernisation of agriculture and livestock farming. By investing in educational initiatives and empowering stakeholders with the requisite knowledge and skills, will accelerate the transition towards sustainable,

efficient, and resilient agricultural practices. A tailored vocational education must be implemented in Thessaly with agricultural colleges in each of the prefectures. Such colleges must have professional lecturers and have access to modern technology. This vocational education should be fully and adequately financed by public means as it is a core responsibility for the government to provide basic conditions for the economic development of Thessaly.

Governance

It is recommended to reinforce modernization of the agriculture sector by providing extension services that offer independent advisory support to farmers. Strengthening cooperatives, improving education within the sector, and enhancing market outlets, perhaps through initiatives such as Protected Designation of Origin (PDO), should also be part of the strategy. These measures collectively contribute to a more sustainable and robust livestock sector.

Government authorities play a crucial role in facilitating the modernisation process of the livestock and agriculture sector. Their involvement is pivotal in assisting the sector's recovery efforts through various key initiatives. These include replenishing lost livestock, offering independent extension services, formulating policies aimed at enhancing farming efficiencies, and engaging in information exchange with stakeholders on relevant issues such as flood prevention, farming in flood-prone areas and developing policies aiming to develop the sector.

However, it is imperative to acknowledge that there exists a lack of trust in the effectiveness of government agencies among stakeholders. This mistrust extends to concerns regarding compensation and the revitalization of the sector. The strained relationship between primary producers and government bodies must be recognized as a critical point of concern in any comprehensive rehabilitation plan.

It is imperative for stakeholders to come together, pooling their expertise and resources, to address these challenges collaboratively. By fostering transparency, accountability, and open communication channels, government authorities can effectively engage with

stakeholders and gain their trust and support in developing a road map to modernise the sector.

In conclusion, the active involvement and collaboration of government authorities are indispensable for the successful modernisation and revitalisation of the livestock and agriculture sector. It is imperative to address existing challenges and build constructive relationships to pave the way for sustainable growth and development in the sector.

Conclusions

- **Rehabilitation strategies:** Develop comprehensive rehabilitation strategies that address both immediate concerns and long-term modernization goals. Prioritize funding allocation for infrastructure repair, livestock restocking, and adoption of advanced farming practices.
- **Information campaigning:** Establish an information platform to disseminate updates, guidelines, and resources related to flood prevention, compensation procedures, and sector rehabilitation. Enhance communication channels between government authorities and stakeholders to foster transparency and trust.
- **Governance enhancement:** Strengthen collaboration between government authorities, farming organizations, and universities to develop and implement policies conducive to sector modernization. Address concerns regarding the effectiveness and transparency of government agencies to build trust among stakeholders.
- **Education and capacity building:** Invest in educational programs and extension services to equip farmers and farm workers with the necessary knowledge and skills for modern agricultural practices. In the education and capacity building sound understanding of the business aspects of agriculture has an important place. If the business is not analyzed, farmers will not change. Provide subsidies and incentives to encourage participation in training and education initiatives.

Concerning the groundwater situation in Thessaly, the escalating use of water, particularly for activities like irrigation, exceeds the natural replenishment rate. This is an unsustainable water balance, posing consequences for the agricultural and livestock sectors. It is urgent

to alter practices, aiming to establish long-term sustainability in the region. Scarce irrigation is best utilized for high value production like legumes and fruits, rather than high-water demanding crops other land uses that consume scarce irrigation water and have limited economic value.

Ultimately, the establishment of a comprehensive Policy and Management Response system is essential. This would require the collaboration of the government, agricultural authorities, and water management agencies to implement policies and regulations aimed at monitoring and controlling water usage. Such measures may involve promoting water-efficient irrigation techniques, enforcing water conservation practices, and offering incentives for adopting sustainable practices.

In order to ensure the effectiveness and objectivity of this initiative, the study should be commissioned through a reputable university, with the collaborative assistance of the Ministry of Agriculture. Such a partnership will bring academic rigor to the research process and ensure that the study's findings are well-founded and actionable. Additionally, involving the Ministry of Agriculture will ensure that the study aligns with practical considerations and can be integrated seamlessly into broader agricultural policies and practices.

A process needs to be undertaken to improve the agricultural innovation capacity in Thessaly. Such a process should include the following stakeholders in this process: Farmer associations, the agroindustry, HAO Demeter, School of Agriculture of University of Thessaly, as well as Ministries dealing with agriculture, education, environment, infrastructure and economy, financial institutions and any other stakeholder willing to contribute to this process. In order to facilitate innovation within the agricultural sector, a good system for communication between farmers, e.g. with study groups, extension workers and agricultural research needs to be developed and put in place. Regarding financing, the farmers will be the ones directly benefiting from the results and therefore have a responsibility. In order to prevent some farmers from shying away from this responsibility it is necessary to initiate a legislative action that ensures that all farmers contribute equitably by paying a fee, else farmers will be tempted to want a free ride, reaping the benefits but not helping shoulder the costs. The size of the fee that each farm should contribute should be based not on the acreage of the farm but its output, so a fee per type of livestock and crop multiplied by number of livestock and hectares per crop or similar such algorithm that would ensure that the contributions of each farm are fair and in proportion to their revenues. It is advised to

implement a 50/50 cost sharing model whereby the public and the private sector contribute 50% each for an initial period of 10 years, upon which it would be evaluated to ascertain if public funds are still necessary or if some changes to the financing mechanism would be needed.

Interbasin water transfer from the Achelous Basin to the Pineios Basin must be implemented in order for Thessaly to continue being a viable agricultural region. A dialogue involving the stakeholders in the prefectures of both basins needs to be initiated and a balanced arrangement implemented with adequate coverage of the environmental, economic and social consequences as well as an equitable distribution of the benefits that the water transfer yields.

Farmers are often reliant on subsidies and these can therefore serve as an effective tool in lowering water usage. Having a strong and sustainable agricultural economy in Thessaly is important for Greece and subsidies should therefore be used to stimulate Thessaly's agricultural sector but geared more towards crops that either consume less water or generate higher revenues per m3 utilized.

A significant amount of the energy expenditure by Thessalian farmers is devoted to pumping up groundwater for irrigation. Whereas the electricity prices are set by the electricity companies, the government directs these prices. It would be a shame if the EU Common Agricultural Policy support program is essentially funding the depletion of Thessaly's groundwater as this will likely cause the collapse of the region's agricultural sector.

By reallocating subsidies so that farmers are encouraged to cultivate crops such as sesame that can be rainfed or higher value crops that utilize much less water will promote the survival of the region as a whole by conserving water and energy. Subsidies need to support sustainable agriculture and promote investments that engender greater food security, climate resilience and market competitiveness. Subsidies should also be designated for crops that add value by having EU labels for Protected Designation of Origin (PDO) or Protected Geographical Indications (PGI).