Università degli Studi della Tuscia di Viterbo
Dipartimento per l'innovazione nei sistemi biologici, agroalimentari e forestali

Corso di Dottorato di Ricerca in

SCIENZE, TECNOLOGIE E BIOTECNOLOGIE PER LA SOSTENIBILITÀ
XXXIV ciclo

Main role of agro-industries in the agroecological transition: public policies and private initiatives

(s.s.d. AGR/01)

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Contents

SHORT ABSTRACT

The transition of the agricultural sector towards agroecology and sustainability seems to be an ongoing process. The agricultural sector is “pushed” by a regulatory framework more focused on environment issues and “pulled” by subsidies linked to the adoption of environmental practices supported by policies and private supply chain initiatives promoted by the market. In this perspective, the research question that prompted the realization of this thesis project arises. Understanding how effectively the supply chain can create synergies between the actors involved, by researching and experimenting a replicable and adaptable methodology that can be used in any context of agricultural production. So, identify economic impacts of public policies and private initiatives and how those can “pull”, or “push” the case study’s farms to diversify their cropping systems in compliance to the main agroecology principals. To answer at these questions and propose a methodological strategy that can be replicated in the major production contexts, it was decided to identify the case study on a private pro agroecology initiative that is part of a highly industrialized Italian agricultural context: the "Carta del Mulino" initiative promoted by Barilla. After case study identification, we define a stable panel of farms involved in economic surveys. In those farms real farms data was carried out and elaborated. Then we define a methodological approach based on a new experimental tool that considering 5 years of future farm’s utilized agricultural area (UAA) in three different production scenarios. The results carried out made it possible to identify the action of public policy and private initiative in the transition of the agricultural system towards agroecology. The case study showed positive results and made it possible to quantify the economic impact and crop diversification impact that farms have in the different production schemes considered.

INTRODUCTION

Since the 70s, agricultural systems have focused on maximizing productivity and profitability (Tilman *et al.*, 2001). However, this intensive model in a few years has accelerated the exploitation of natural resources (Foley *et al.*, 2005).

During the opening intervention of the 2nd International Agro-ecology Symposium (FAO, Rome 3-5 April 2018), the FAO's director general, Josè Graziano da Silva, urged the transition to healthier and more sustainable food systems. In the same intervention he declared that only the agroecology can contribute to this transition. According to Gliessman (1998) the agro-ecology is defined like the science of applying ecological concepts and principles for the design and management of sustainable agro-food systems. Among the most suitable strategies for this step, there is the diversification of agricultural systems, through the introduction of new agronomic practices and organizational models at farm and supply chain level (Francis *et al.*, 2003). This reading is also confirmed, for the European countries, by the new CAP (Common Agricultural Policy) reform proposal that continues to move on Fischler reform path. In fact, this has strengthened tools such as cross-compliance, greening, new proposal on ecological payment schemes (1st pillar) and has plan again agro-environmental schemes for farmers and others actor of the supply chain (2nd pillar) (European Commission, 2018b).

The research of sustainability attribute in the food products seems to be very interesting looking at market shares increasing and opportunities for future golden shopper demand. The results of Grunert et al. (2014) shows that consumers associate the sustainability concept to aspects of environmental protection. There is a growth in attention on individuals as a means of tackling environmental problems in Western democracies (Barr, Gilg and Shaw, 2011). So, an increasing number of consumers demand and prefer food with sustainability claims.

Following neoclassical economic theory and approaches, where the market it is ruled by two actors, consumers (demand) and agro-industries (supply), consumers will pay more attention to sustainability of the food product and producers will be include this new quality attribute in their product in an efficient way.

The agri-food companies answer at this demand with sustainable products by adopting new approaches to the supply of raw materials. A first approach consists in using raw materials certificated by sustainability certification schemes. The use of this tools during the last years (from 2011 to 2016) is testified by the increase of hectares of agricultural areas affected by different certification schemes that call for sustainability in the world: from a minimum of 26.8% (sugarcane) to a maximum of 187% (cocoa) (Lernoud *et al.*, 2018). Recently agro-industries have promoted others approaches based on private sustainable supply chain initiatives, and they have started communicating sustainability-claim related information about food to consumers, introducing labels and logos in-store and on-pack (Matopoulos *et al.*, 2001; Blasi, Ruini and Monotti, 2017). However, it is very important to understand which are the certifications and private initiatives that facilitate the introduction of agroecological principles and practices at farm level, and if, at the same time, that are recognized by consumers as "sustainable attributes".

So, the transition of the agricultural sector towards agroecology and sustainability seems to be an ongoing process. The agricultural sector is "pushed" by a regulatory framework more focused on environment issues and "pulled" by subsidies linked to the adoption of environmental practices supported by policies and private supply chain initiatives promoted by the market. This scenario can be showed in the following scheme (Figure 1).

In this perspective, the research question that prompted the realization of this thesis project arises. Understanding how effectively the supply chain can create synergies between the actors involved, by researching and experimenting a replicable and adaptable methodology that can be used in any context of agricultural production. So, relating to the figure 1 identify economic impacts of public policies and private initiatives and how those can "pull", or "push" the case study's farms to diversify their cropping systems in compliance to the main agro-ecology principals. Understand how much this shift can create costs or benefits for the farms and identify the extent of the same. Therefore, looking at the entire supply chain, we want to try to understand if this system of rewards (public and private) is sufficient for the greater efforts that all or some of the players support to adapt to these new production methods. At the same time, it is of great importance to evaluate the current strength of public initiatives in which farms highly specialized in the production of arable land commodities adhere. The current public initiatives dictated by the CAP, in a context of specialized production on the production of arable land, condition the choices of the farmer. The aim is therefore to evaluate the importance of these practices both from an economic point of view and in terms of diversification of the context in which highly specialized farms are present.

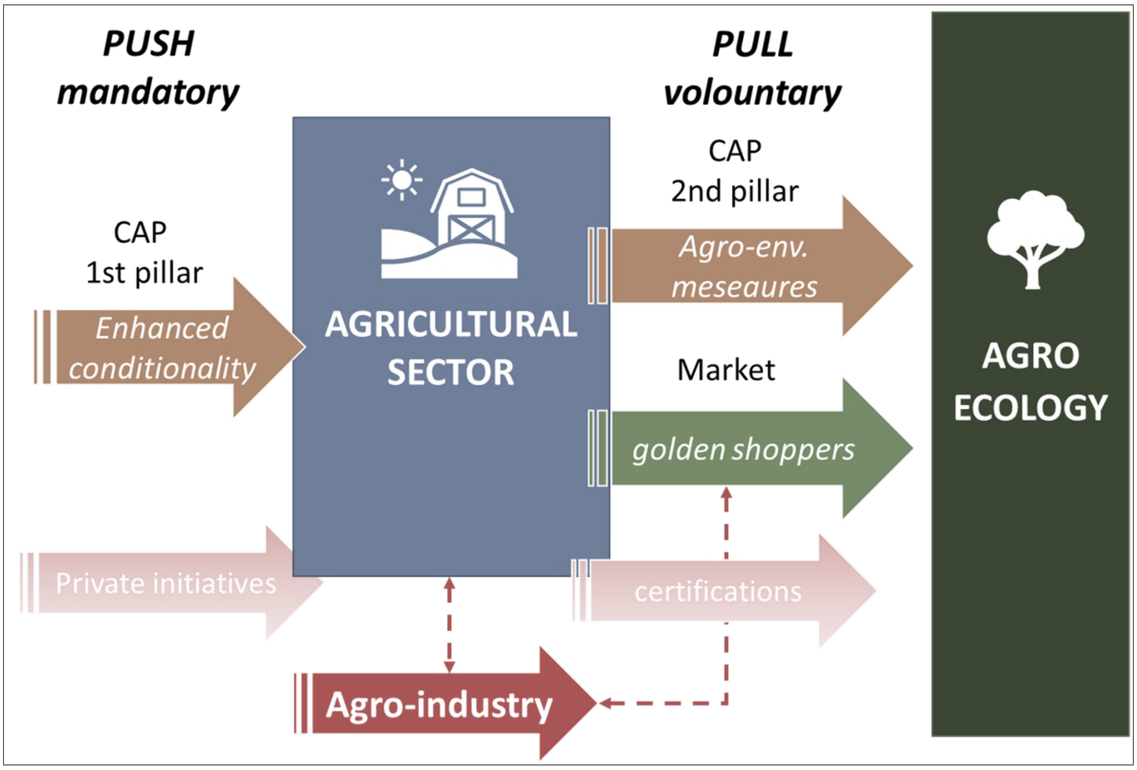


Figure 1 – Transition of the agricultural sector to the agroecology. (Source: own elaboration)

To answer at these questions and propose a methodological strategy that can be replicated in the major production contexts, it was decided to identify the case study on a private pro agroecology initiative that is part of a highly industrialized Italian agricultural context: the "Carta del Mulino" initiative promoted by Barilla. The chapter two illustrate the case study selected and the area considered.

After the case study identification, we define a methodological approach (Chapter 3). A stable panel of farms involved in economic surveys. In those farms real farms data was carried out and elaborated. Then we define a methodological approach based on a new experimental tool that considering 5 years of future farm's utilized agricultural area (UAA) in three different production scenarios.

Finally, the results reported in chapter 4 made it possible to identify the action of public policy and private initiative in the transition of the agricultural system towards agroecology. The case study showed positive results and made it possible to quantify the economic impact and crop diversification impact that farms have in the different production schemes considered.

CHAPTER 1 – STATE OF THE ART

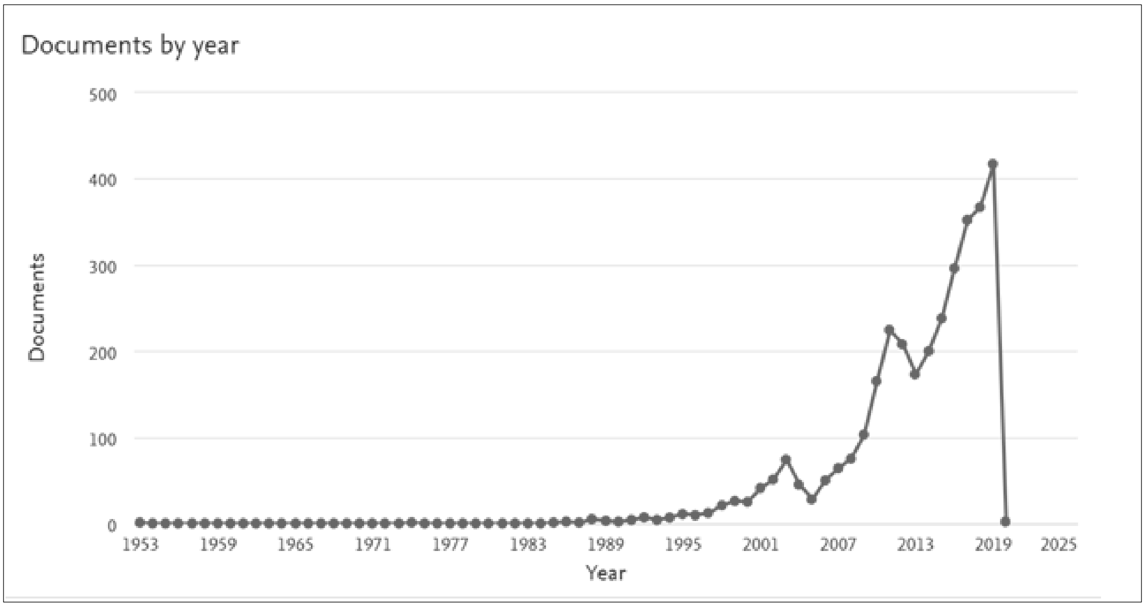
THE AGROECOLOGICAL TRANSITION: AN ONGOING PROCESS

The aim of this chapter is to define and illustrate all the "actors" and the "forces" involved in this on-going transition of the agricultural sector to the agroecology (Figure 1).

1.1 A new shared vision: agroecology

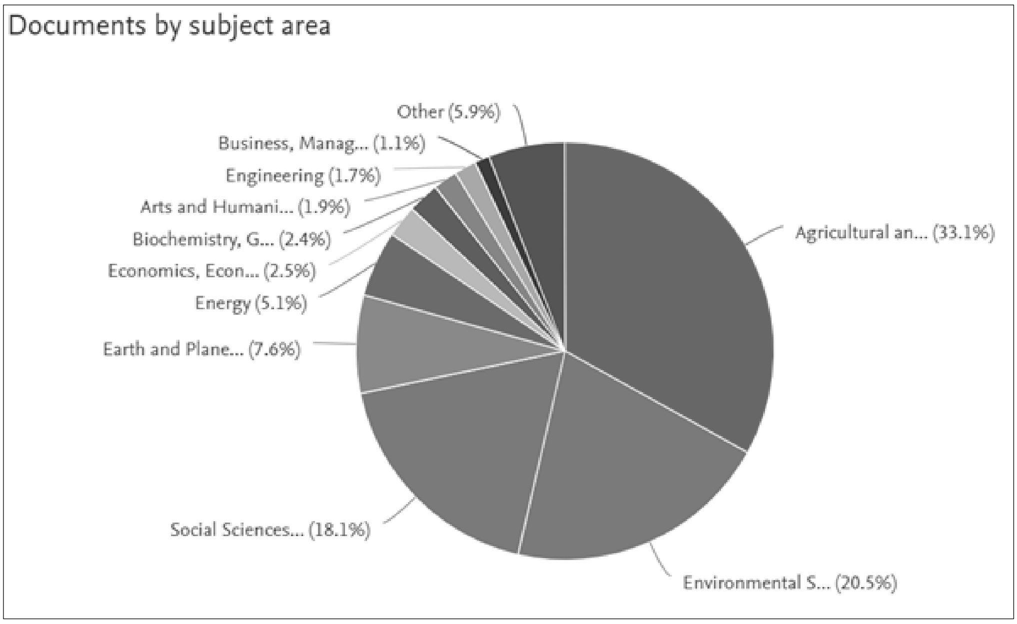
The agroecology concept is widely defined by the literature during the years. The concept starts from 1928 when K.H. Klauges introduced the concept of "crop ecology" (Klages, 1928) and takes shape throughout the twentieth century with a succession of studies and research which led to define the current principles (Francis *et al.*, 2003). The most pertinent definition that illustrate the finish line of the previous scheme (Figure 1) comes from Gliessman (1998). He defines agroecology like "the application of ecological concepts and principles to the design and management of sustainable agroecosystems". This definition wants to represent the ecological coexistence of agriculture and biodiversity in the same territory with the aim of improving agricultural systems by imitating and enhancing the natural processes of the ecosystem (Altieri and Nicholls, 2012).

The primary objective of agroecology is the interaction and productivity of the agricultural system as a whole, and not looking only of individual crops (Silici, 2014). The concept of agroecology is not recent but its spread dates to the last twenty years, in which it has taken on different meanings until projecting itself into a much wider context than the agricultural sector, assuming a social dimension attributable to a critical reflection on the models of food consumption (Wezel and Soldat, 2009). The bibliography on agroecology as well as speaking of the technical topics at farm level, in the last twenty years started to talk about it as a complex system that also includes the social and economic sphere (Brym and Reeve, 2016). Foley at al. (2003) talk about the agroecology like the "ecology of the whole food systems". So, the scientific society started to think agroecology needs to involve all parties, from scientist to producer to processor to marketer to consumer, if the goal is to base the food system on scientific foundations that can handle complexity and change. For doing this more consumers need to understand the connections among agriculture, their food, their health, and their environment. This shared vision has led to growth of interest of the scientific world to the agroecology, evidenced by the exponential increase in publications from 2003 to 2019. The following graph (Graph 1) shows the results on Scopus database of the paper by year whit the word "agroecology" on title, abstract and key words.



Graph 1- Results on "Scopus" of the paper by year whit the word "agroecology" on title, abstract and key words (Source: www.scopus.com)

This growing attention it is not only on the "Agricultural and biological science", but there is a growing in "Social science" and "Economics – Econometrics Science". The following graph (Graph 2) shows the results on "Scopus" of the paper by area whit the word "agroecology" on title, abstract and key words.



Graph 2 - Results on "Scopus" of the papers by subject area whit the word "agroecology" on title, abstract and key words (Source: www.scopus.com).

The most important paper in citation and diffusion talks about agroecology like an instrument to promote the new "Green Revolution". In the face of recurrent global food crises, institutions of the corporate food regime propose a new Green Revolution coupled with a continuation of neoliberal economic policies. Because these are causes of the crises to begin with, this approach can worsen rather than end hunger. Building a countermovement depends in part on forging strong strategic alliances between agroecology and food sovereignty (Holt-giménez and Altieri, 2013).

More of those shows link between agroecology and social topics in different part of the world. It is very important the contribution from Altieri and Toledo (2011) that provides an overview of what they call 'agroecological revolution' in Latin America. An assessment of various grassroots initiatives in Latin America reveals that the application of the agroecological principals can bring significant environmental, economic, and political benefits to farmers and rural communities as well as urban populations in the region. In definitive the paper shows the link between nature, ensuring food sovereignty and empowering farmers (Altieri and Toledo, 2011).

So, today agroecology is described by literature like a science, a set of practices and a social movement. The case studies mainly involves small farms in developing countries where the dynamics of production specialization related to the production of commodities for the international market have been established in a very short time (Wezel and Soldat, 2009). Therefore, it is a discipline that aims to bring industrial agriculture towards an alternative agricultural paradigm that encourages the local / national food production of small family farms based on the introduction of innovative solutions at the local level, on the available resources.

Although the target of farmers is defined in a context of small-scale agriculture, there is a growing attention to these new models by companies and supply chains oriented to industrial production.

1.1.1 Main principles and practices

To define an agroecological system, it is first necessary to define the principles used in management and design of this kind of productive scheme.

Agroecology uses ecological concepts and principles for the management of sustainable agroecosystems with the replacement of external inputs through natural processes, such as soil fertility and biological control. It is the holistic study of the agroecosystem including human elements and natural elements (Altieri, 1995). The reduction of external inputs and the consequent improvement of the efficiency of agricultural systems come from the better use of natural resources and the beneficial interactions that are unsaturated within the farm. The use of agroecological principles in the design and management of cultivation systems improves the biodiversity of agroecosystems which allows to increase the immune, metabolic, and regulatory processes (Gliessman, Engles and Krieger, 1998). According to Altieri and Nicholls (Altieri and Nicholls, 2012) the agroecological principals that can create a resilient farming system are the following:

1. Optimize the decomposition of organic matter and the nutrient cycle over time by recycling biomass.
2. Enhance functional biodiversity (natural enemies, antagonists, etc.) with the aim of strengthening the "immune system" of agricultural systems.
3. Preserve organic matter by improving the biological activity of the soil to provide the most favorable soil conditions for plant growth and development.

4. Improve the conservation and regeneration of soil and water resources and agrobiodiversity by minimizing losses in terms of energy, water, nutrients, and genetics.
5. Acting in time and space at the field and landscape level by diversifying the species and genetic resources within the agroecosystem.
6. Promote ecological key processes and services through biological interactions and synergies between different agrobiodiversity components.

These principles are the basis of the agroecological transition in order to design and / or re-design resilient and bio-diverse agricultural systems, efficient from an energy point of view and able to conserve natural resources (Altieri, Nicholls and Montalba, 2017).

However, the principles illustrated must adapt to each specific circumstance of agricultural production in terms of physical, pedological and socio-economic characteristics. So, they can be applied by way of various techniques and strategies. The application of these principles will lead to different effects on productivity, stability, and resilience within the agricultural system, based on the different territories, resource constraints and markets involved (Altieri, 2004). The common thread that binds the rules we have mentioned is certainly the concept of diversification of agricultural systems. The diversification practices introduced in a system such as, for example, blends of crop varieties, intercropping systems, agroforestry systems and zootechnical integration enhance the positive effects of biodiversity on productivity. These increases derive from the strengthening and exploitation (in its positive meaning) of natural mechanisms such as: complementarity between plant-animal; better use of sunlight; better land use; natural regulation of parasite population (Altieri and Nicholls, 2012).

New agroecosystem projects, such as differentiated ones , provide for different practices and strategies, each with effects on productivity, stability and resilience within the farming systems (Kremen and Miles, 2012). The main key of the agroecological practices is restore agricultural diversity in time and space. The main practices with a high agroecological value that the scientific literature recognizes as key to improving diversification within agricultural production systems are listed below (Altieri, 1995; Gliessman, Engles and Krieger, 1998).

- Crop Rotations: temporal diversity in the form of cereal-legume sequences. Nutrients are conserved and provided from one season to the next, and the life cycles of insect pests, diseases, and weeds are interrupted.
- Polycultures: cropping systems in which two or more crop species are planted within certain spatial proximity result in biological complementarities that improve nutrient use efficiency and pest regulation thus enhancing crop yield stability.
- Agroforestry Systems: trees grown together with annual crops in addition to modifying the microclimate, maintain and improve soil fertility as some trees contribute to nitrogen fixation and nutrient uptake from deep soil horizons while their litter helps replenish soil nutrients, maintain organic matter, and support complex soil food webs.
- Cover Crops and Mulching: the use of pure or mixed stands of grass- legumes e.g., under fruit trees can reduce erosion and provide nutrients to the soil and enhance biological control of pests. Flattening cover crop mixtures on the soil surface in conservation farming is a strategy to reduce soil erosion and lower fluctuations in soil moisture and temperature, improve soil quality, and enhance weed suppression resulting in better crop performance.
- Crop- livestock mixtures: high biomass output and optimal nutrient recycling can be achieved through crop- animal integration. Animal production that integrates fodder shrubs planted at high densities, intercropped with improved, highly productive pastures and timber trees all combined in a system that can be directly grazed by livestock enhances total productivity without need of external inputs.

These diversification schemes appear to be multifunctional as their action could imply favorable and simultaneous changes in various components of the farms systems (Gliessman, Engles and Krieger, 1998). The complete view of the agroecological practices in the farm's holistic point of view comes from Caporali, 1991. The design of a production system according to the "rules" of agroecology aims to create an agro-ecosystem that uses the basic model of an ecosystem. The resulting definition is that an agro-ecosystem is an ecosystem used for agricultural purposes: producers (crops) and consumers (farm animals) are introduced by the farmer, while the decomposers are typical of the native ecosystem. Crops and livestock are biotic components selected through genetic improvement and they constitute elements of biodiversity that derive from the co-evolution of nature and culture. The technical means (machines, fertilizers, irrigation, etc.) and human resources (labor, capital, etc.) used in agriculture represent the additional elements of the creation and management of the agro-ecosystem. Agriculture is therefore made up of a complex system of organization of natural and anthropogenic resources and the sustainability of the agro-ecosystem depends on bio-physical and socio-economic factors (Caporali, 1991).

In this wake the Food and agricultural Organization of United Nations in 2018 publish a handbook called “The 10 elements of agroecology: to sustainable food and guiding the transition agricultural systems” whit the main aim to helping countries to operationalize agroecology (FAO, 2018b). By identifying important properties of agroecological systems and approaches, as well as key considerations in developing an enabling environment for agroecology, the 10 Elements are a guide for policymakers, practitioners, and stakeholders in planning, managing, and evaluating agroecological transitions. Fao, starting from the scientific literature, resume the main actions to promote the agroecological transition by the following features:

1. Promote Diversity. The Diversification is key to agroecological transitions to ensure food security and nutrition while conserving, protecting, and enhancing natural resources.
2. Co-creation and sharing of knowledge. Agricultural innovations respond better to local challenges when they are co-created through participatory processes.
3. Synergies. Building synergies enhances key functions across food systems, supporting production and multiple ecosystem services.
4. Efficiency. Innovative agroecological practices produce more using fewer external resources.
5. Recycling. More recycling means agricultural production with lower economic and environmental costs
6. Resilience. Enhanced resilience of people, communities and ecosystems is key to sustainable food and agricultural systems.

7. Promote human and social values. Protecting and improving rural livelihoods, equity and social well-being is an essential topic for sustainable food and agricultural systems.
8. Culture and food traditions. By supporting healthy, diversified and culturally appropriate diets, agroecology contributes to food security and nutrition while maintaining the health of ecosystems.
9. Responsible governance. Sustainable food and agriculture require responsible and effective governance mechanisms at different scales – from local to national to global.
10. Circular and solidarity economy. Circular and solidarity economies that reconnect producers and consumers provide innovative solutions for living within our planetary boundaries while ensuring the social foundation for inclusive and sustainable development.

Those 10 Elements of Agroecology are interlinked and interdependent. The following figure resume all the connections between the elements (Figure 2). As we can see, the proposed scheme shows the importance of the connection between all the elements that contribute to the promotion of agro-ecological principles. Synergy plays a central role between agronomic actions (green) and social actions (yellow). Governances and the economy have the task of conveying these actions (red).

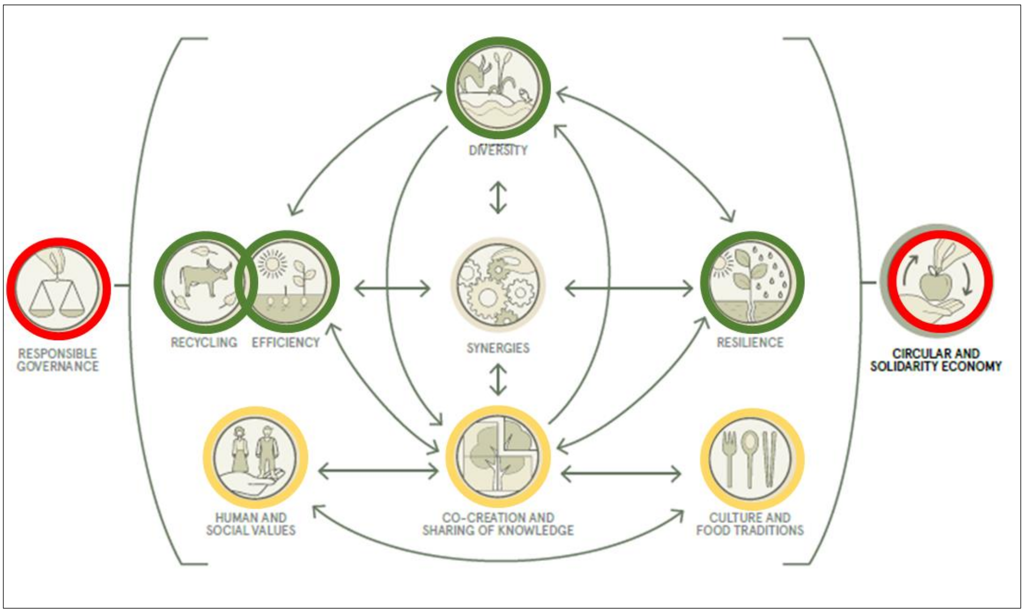


Figure 2– The ten elements of agroecology by FAO. (Source: adapted from FAO, 2018)

1.1.2 Relations between agroecological practices and ecosystem services.

Scientific literature shows that biodiverse farming systems (intercropping, agroforestry, integrated livestock farming systems) support a range of ecosystem services, as well as reducing in the long run, the need for external inputs for the farm (Lithourgidis *et al.*, 2011; IPES-Food, 2016; Wilson and Lovell, 2016). Through the application of the principles and practices described above, which tend to replicate natural ecosystems, agroecology contributes to the construction of more complex agroecosystems.

By analyzing the environmental and ecological impacts that could result from the application of agroecological practices, it has been shown that greater biodiversity in soils can improve water use, nutrient absorption, and resistance to disease by crops Through the application of crop rotation models based on classical agronomic principles, it is possible to conserve nutrients and keep them available from one season to the next, as well as interrupting the life cycle of parasites, pathogens, and weeds (Kremen and Miles, 2012). Practices such as mulching, and cover crops can reduce erosion and replenish the soil with nutrients (Smith, Atwood and Warren, 2014). Conservative agriculture strategies, which through the reuse of plant residues released from the previous crop allows to reduce soil exposure to erosion dynamics and to reduce fluctuations in humidity and temperature. The review proposed by Julia Rosa-Schleich et al., 2019 shows that environmental benefits of agroecological diversification practices are numerous and among these should be mentioned: increase of biodiversity; improvement of the control of pests, diseases and weeds; improvement and stability of soil health; improvement of water and nutrient management (Rosa-Schleich *et al.*, 2019).

So, agroecology has been suggested as a promising concept for reconciling agricultural production and environ- mental sustainability by optimizing ecological processes that deliver ecosystem services to replace external inputs. A recent paper by Boeraevea et al. 2020 provides an assessment of seven ES based on 14 indicators in three agroecological farming systems (AFS) and thirteen of their adjacent conventional farming systems (CFS). Based on field-scale measurements spread over three years, the findings suggest that the studied AFS succeed in providing a wider array of regulating services than their neighboring CFS. The results show a soil aggregate stability and soil respiration rates in general more supported in AFS, which also show lower pest abundance. But on the other hand, CFS show higher grain production and higher performance for two out of three fodder quality indices (Boeraeve *et al.*, 2020).

Through the search for an ever better environmental dimension, agroecology aims to build self-sufficient, healthy, and unpolluted systems capable of providing ranges of food and energy. Through an efficient use of resources (such as the use of water and energy) these types of systems could also help build resilience and, at the same time, increase efficiency. In this regard, it is necessary to define two concepts considered pivotal in the ecological and environmental fields: resilience and efficiency. Holling define the ecological resilience like the ability of natural systems to absorb shocks while maintaining their functions, a capacity that is measured by the degree of disturbance that a natural system can absorb before the system itself changes its structure, changing variables and processes that control its behavior (Holling, 1973). The concept of efficiency is defined by FAO 2018 as an emerging property of agroecological systems. By optimizing the use of natural resources such as soil, air, solar energy, water, agroecology uses fewer external resources, reducing costs and negative environmental impacts (FAO, 2018a).

The environmental benefits that could derive from the application of agroecological practices must, however, be contextualized and various factors such as farm's size, climate and infrastructures that would affect the entire environmental dimension must be considered. Although it has now been established in the literature that a production system based on agro-ecological principles can improve its sustainability, both reducing the impacts on natural resources and increasing the supply of ecological services, there are not as many certainties regarding the potential economic improve for the operators of these systems. According to the global literature of the last twenty years, using local resources, the food impact on regional markets has the potential to improve local economies and eliminate the negative of the free market on the lives of small local producers (Altieri and Toledo, 2011; CIDSE, 2018; FAO/INRA. *et al.*, 2018). Agroecological approaches should be economically sustainable because the production methods reduce the costs of external inputs and therefore allow greater financial and technical independence, and greater autonomy for producers. Those production methods always seem to be accompanied by significant increases in the added value generated by each work unit (Van Der Ploeg *et al.*, 2019). With the diversification of agricultural production and activities, food producers may be less exposed to market risks such as price volatility or losses due to extreme weather events. Smallholder farmers in particular benefit from agroecology, as they could increase the yield of their crops in a sustainable way, improve their products and nutritional security, and increase their incomes (Van Der Ploeg *et al.*, 2019). Furthermore, agroecology considers externalities for society and the environment, minimizing waste and negative health impacts, and supporting positive externalities such as ecological health, resilience and regeneration (Hooks *et al.*, 2017). In a systemic reading key, these benefits, although often exchangeable on the market, offer an improvement in wellness conditions for the entire society (D'Annolfo *et al.*, 2017).

All this economic point of view with its potential advantages tends to stimulate and motivate smaller and more flexible companies, to experiment with models that are not only ecologically more efficient, but sometimes also economically and socially more sustainable than the application of protocols linked to the regulations of the organic farming (Moore *et al.*, 2014).

Table 1 - Details of DF practices considered in the review proposed by Rosa-Schleich et al 2019. An overview of the ecological and economic benefits at the farm level found and a few key references. (Source: Rosa-Schleich et al., 2019)

	Ecological and economic benefits at the farm level	Key references
Single measures		
1. Cover crops & green manure Crops that are planted between the main food crops during the winter or summer fallow period to provide a constant soil cover.	**Ecological**: higher biodiversity, improved pest control, higher weed control and soil health, reduced soil erosion, improved water and nutrient management, higher carbon sequestration and increased resilience **Economic**: long-term yield improvement, reduced fertilizer and machinery input, higher profitability and less risk	Dabney et al., 2001 Vukicevich et al., 2016 Snapp et al., 2005 Valkama et al., 2015
2. Diversified crop rotation Temporal sequence of different crops grown on the same piece of land (temporal diversification).	**Ecological**: increased biodiversity, improved pest control, higher weed control and soil health, reduced soil erosion, increased nutrient availability and higher carbon sequestration **Economic**: long-term yield improvement, reduced fertilizer input, higher profitability	Doltra and Olesen, 2013 Venter et al., 2016
3. Reduced tillage Reduced tillage includes no-till, direct seeding and/or minimal mechanical soil disturbance through non-turning soil cultivation.	**Ecological**: increased belowground biodiversity, improved pest control and soil health, reduced soil erosion, increased nutrient availability and higher carbon sequestration, improved water management, increased resilience **Economic**: increased long-term yield, fewer machinery costs and reduced labor input	Derpsch et al., 2010 Knowler and Bradshaw, 2007 Snapp et al., 2005
4. Intercropping Characterized by growing multiple cultivars or crop species simultaneously on the same field (spatial diversification).	**Ecological**: improved biodiversity and pest control, higher nutrient management, better soil health and weed control **Economic**: increased yields and reduced agrochemical input, higher profitability and less risks	Duchene et al., 2017 Himmelstein et al., 2017 Letourneau et al., 2011 Nie et al., 2016
5. Agroforestry Defined as the integration of trees and crops on the same land. Agroforestry is a type of intercropping, but integrates woody and herbaceous layers.	**Ecological**: increased biodiversity, enhanced pest and weed control, higher soil health, better nutrient management, greater carbon sequestration and erosion control **Economic**: higher yield and yield stability, reduced agrochemicals, higher profitability	Carsan et al., 2014 Malézieux et al., 2009 Pumariño et al., 2015 Torralba et al., 2016
6. Structural elements Linear features in the landscape that had to be implemented or managed by the farmer.	**Ecological**: increased biodiversity, enhanced pollination and pest control, reduced soil erosion **Economic**: input savings (seeds, fertilizer, pesticides), marginal operation costs (labor savings and energy, machinery depreciation)	Griffiths et al., 2008 Haaland et al., 2011 Holland et al., 2016
Systems (combined measures)		
7. Conservation Agriculture Based on a combination of three principles applied on the field: 1. Minimal mechanical soil disturbance by reduced tillage and direct seeding, 2. Permanent soil cover through the retention of crop residues on the soil surface by cover crops and mulching and 3. A diversified crop rotation or mixture.	**Ecological**: increased biodiversity, enhanced soil health, higher control of pests and diseases and better nutrient and water management **Economic**: improved long-term yields, lower machinery input and higher fuel, time and labor savings	Knowler and Bradshaw, 2007 Mafongoya et al., 2016 Thierfelder et al., 2014 Rusinamhodzi et al., 2011
8. Diversified crop-livestock systems The integration of crops with livestock (spatial and temporal diversification).	**Ecological**: higher biodiversity, enhanced pest and weed control, lower diseases and improved soil health and less erosion **Economic**: high yields, input savings (herbicides, pesticides and fertilizer), increased profitability and reduced risk	Bell et al., 2013 Bonaudo et al., 2013 Nie et al., 2016 Sulc and Tracy, 2007
9. Organic agriculture Farming without the use of agrochemical inputs such as mineral fertilizer and pesticides, thereby relying on ecological processes and biodiversity adapted to local conditions.	**Ecological**: increased biodiversity and pollination, enhanced diseases incidence, better soil health and erosion control, better nutrient and water management, higher carbon sequestration and resilience of the agro-ecosystem **Economic**: higher yield stability and increased long-term advantages, savings through non-use of agrochemicals, higher profitability on the market and lower risk	Seufert and Ramankutty, 2017 Kremen and Miles, 2012 Reganold and Wachter, 2016

1.1.3 *Impacts of agroecological and conventional practices: a review*

What has just been described is part of a review carried out to evaluate the economic and ecological consequences of sustainable agriculture and agroecology. All the information gathered from the literature analyzed and considered relevant for the research to be developed was summarized through tables, presented below. There were reported the practices most analyzed by the studies, of agroecological systems and conventional systems, the relative economic and ecological benefits generated, and the indicators proposed and used for the purpose, where present.

Table 2 - Analysis of agroecological practices and ecological and economic benefits generated based on the analysed literature.

Agro-ecological practices	**References**	**Experimental elements**	**Ecosystem services generated**	**Economic benefits generated**	**Negativity generated**	**Indicators used**
Cover crop	(Rosa-Schleich *et al.*, 2019) (Kremen and Miles, 2012) (Van Der Ploeg *et al.*, 2019)	Literature from Web of Science and Google Scholar Meta-analysis of comparative studies published in the Web of Science Collection of research and studies on European countries	• Biodiversity • Weed control • Soil health • Soil erosion control • Carbon sequestration	•Reduction of pesticide costs • Reduction of fertilizer costs • Long-term effects on yields • Reduction of risk	• Lower yield in the short term • Less stability of the crop	VA/LU=GVP/LU
Diversified crop rotation	(Rosa-Schleich *et al.*, 2019) (Kremen and Miles, 2012) (Dogliotti *et al.*, 2013) (Lechenet *et al.*, 2014)	Literature from Web of Science Survey of 14 family farms located in southern Uruguay Evaluation of 48 conventional and organic arable farming systems in France	• Biodiversity • Control of pests and weeds • Pollination • Soil structure • Nitrogen fertilization • System resilience	• Yield Stability • Reduction of fertilizer costs • Long-term effect on yields • Reduction of work		VA/GVP Isc=KP x Kr x Kd Net Margin
Minimum Tillage	(Rosa-Schleich *et al.*, 2019) (Van Der Ploeg *et al.*, 2019)	Literature from Web of Science and Google Scholar Collection of research and studies on European countries	• Biodiversity • Pollination • Erosion control • Water retention capacity • System resilience	• Yield Stability • Long-term effect on yields • Reduction of machinery costs • Reduction of manpower	• Weed control • Increase of herbicide costs • Increased risk	VA/WORKER GVP/WORKER Household income worker
Diversified structural elements	(Rosa-Schleich *et al.*, 2019) (Dogliotti *et al.*, 2013) (Van Der Ploeg *et al.*, 2019)	Literature from Web of Science Survey of 14 family farms located in southern Uruguay Collection of research and studies on Eu. countries	• Biodiversity • Pollination • Erosion control • Soil health • Availability of nutrients • Carbon sequestration	• Yield Stability • Reduction of herbicide and pesticide costs • Reduction of machinery costs	• Possibility of increasing weeds	VA/GVP Field surveys of the number of Apoidea

Intercropping	(Rosa-Schleich *et al.*, 2019) (Casagrande *et al.*, 2017)	Literature from Web of Science and Google Scholar Analysis of 193 French farms and in-depth interviews with 29 of them	• Pollination • Pest control • Soil health • Water regulation • Increased system resilience	• Greater harvest • Stability of the crop • Reduction of pesticide and fertilizer costs	• Increase in machinery costs • Increase of working hours	C (q1,q2) < C (q1,0) + C(0,q2) if q1 > 0 and q2 > 0

The table just presented compares the ecological and economic benefits obtained through the application of agro-ecological practices reported in the literature. The studies and the authors analysed propose a series of indicators for the evaluation and quantification of the benefits obtainable from each practice. For the practices of cover crop, diversified rotation, minimum tillage and structural elements, reference is made to the study by Van der Ploeg et al., 2019, which proposes a technical-economic model to be able to compare the income generated by agroecological practices with those generated from the practices of conventional systems (Van Der Ploeg *et al.*, 2019). The model is based on the ratio between Value Added and the Gross Value of Production (VA/GVP) realized in agroecological production. Farmers try to maximize the VA from a given GVP. The agricultural economy and the institutions surrounding agriculture consider the Added Value determined by off-farm prices and certain cost levels. The guiding principle is to increase the total production (GVP) achieved per work unit (GVP / LU), according to Ploeg this translates into a continuous expansion of the scale or a reduction in incoming labour. The same study explains how mixed agriculture creates synergistic circuits that strengthen resilience and help build economies of scope rather than economies of scale, thus contributing to further cost reductions and consequent increases in the VA/GVP ratio. In this regard, for practices such as intercropping, is presented the following formula:

$$q_1\text{C}\ (,q_2) < \text{C}\ (q_1,0) + \text{C}(0, q_2) \qquad \text{if}\ \ q_1 > 0 \text{ and } q_2 > 0$$

It expresses how the costs of producing two products (q1 and q2) together are lower than producing them individually, especially if they are linked by synergistic loops. For diversified crop rotation, a further indicator is proposed by the study by Lechenet et al., 2014: the ISC (Lechenet *et al.*, 2014). It is an indicator that estimates the coherence of the crop sequence about the potential for reducing inputs, addressing the effects of rotation on the crop, on pathogens, pests, and weeds. The Isc varies on a qualitative scale between 0 and 10 and is calculated with the following equation:

$$Isc = kp\ X\ kr\ X\ kd$$

Isc is based on the assessment of the effects of the previous crop on the current crop (kp), with respect to the development of pathogens, pests, and weeds, to soil structure and nitrogen supply. Kp is corrected by two factors considering the crop frequency (kr) and the crop rotation whole diversity (kd).

Table 3 - Analysis of conventional practices and ecological and economic benefits generated based on the analysed literature.

Conventional techniques	References	Experimental elements	Ecosystem services generated	Economic benefits generated	Negativity generated	Indicators used
Ploughing and others cultivation operation	(Rosa-Schleich *et al.*, 2019) (Kremen and Miles, 2012) (Van Der Ploeg *et al.*, 2019)	Literature from Web of Science and Google Scholar Meta-analysis of comparative studies published in the Web of Science	• Production of food and income	• Higher yield of short term crops	• Higher costs of machinery and fuel • Higher labor costs • Increased risk of soil erosion	Meta-analysis of comparative
Chemical Pesticide use	(Rasul and Thapa, 2004) (Kremen and Miles, 2012) (Lechenet *et al.*, 2014)	Comparison between conv. and agro-ecological oriented farms Meta-analysis of comparative studies published in the Web of Science	• Production of food and income	• Higher crop yield in the short term • Lower risk	• Higher costs of pesticides • Serious environmental and health problems • Soil acidification	I-Pest Chemical analysis of the soil samples taken
Monoculture	(Rasul and Thapa, 2004)	Comparison between conv. and agro-ecological oriented farms located in 13 villages of Bangladesh	• Production of food and income	• Higher crop yield in the short term • Lower risk	• Increase of weeds • Reduction of biodiversity • Poor system resilience	ICD=(Pa+Pb+Pc+…+Pn)/Nc
Use of synthetic fertilizers	(Rasul and Thapa, 2004) (Glendining et al., 2009) (Lechenet et al., 2014)	Comparison between conv. and agro-ecological oriented farms Evaluation of 48 conventional and organic arable farming systems in France	• Production of food and income	• Greater profitability of the crop in the short term • Greater gross profit margin • Lower risk	• Contamination of water bodies • Reduction of the organic matter content in the soil	TFP Chemical analysis of soil samples

The second table summarizes the information concerning conventional practices taken from the literature (Tab. 3). In the study conducted by Lechenet et al., The environmental impact of crop systems and their dependence on external inputs is evaluated with the I-Pest indicator and with estimates of fuel consumption and nitrogen fertilizers. I-Pest is a predictive indicator that evaluates the environmental impact of the use of pesticides as a risk of contamination of air and water (Lechenet *et al.*, 2014).

The study conducted by Rasul and Tapa 2013, although it's not recent, is significant for the index used. They used the Crop Diversification Index (ICD) to evaluate the impact of the monoculture in 13 Bangladesh farms. Crop diversification is analysed based on three criteria such as intensity, diversification and mixed coverage and using the formula developed by Bhatia:

$$ICD = \frac{(\,Pa + \ Pb + \ Pc + \ldots + Pn)}{Nc}$$

where Pa it's a proportion of sown area under crop a; Pb it's a proportion of sown area under crop b; Pc it's a proportion of sown area under crop c; Pn it's a proportion of sown area under crop n; Nc is the number of crops (Bhatia, 1965).

The Glendining et al. study gives a method for examining the sum of economic value of an activity by expressing all components on the same basis is to analyse the total factor productivity: TFP (Barnett, Landau and Whelam, 1994). Total factor productivity (TFP) is the ratio of the economic outputs from a system to the inputs. Barnett et al. (1995) showed how this concept could be used to include environmental considerations by attributing a cost to each of the resources and to the effects of each burden on the environment. TFP is used as an index and normally calculated at the optimum yield response. This is the value- weighted sum of the outputs from a farming system divided by the cost-weighted sum of the inputs:

$$TFP = \frac{\sum_{j=1}^{m} P_j Q_j}{\sum_{i=1}^{n} W_i X_i}$$

where Wi is the cost of each of n input factors used at rate Xi, and Pj is the value of each ofm outputs yielding a quantity Qj each. If TFP is greater than 1.0 and remains so for a number of years a system can be said to be sustainable economically (Glendining *et al.*, 2009).

Based on the information obtained from the literature, a summary table has been developed, presented below, which sets up the relationships between some environmental and economic benefits and the main agroecological practices compared to conventional ones (Tab. 4). The scheme through a colour symbology attributes a low, medium, or high level for each benefit associated with each individual practice. Where the literature did not provide sufficient information to be able to attribute a level of benefit, the practice was marked in grey.

Table 4 - Level of ecological and economic benefits by agroecological practices and conventional practices.

	Agro-ecological practicies					Conventional practicies		
	Cover crop	Crop rotation	Minimum tillage	Diversified structural elements	Intercropping	Ploughing and others cultivation operation	Use of pesticide and fertilizers	Labour
Agro-ecological Benefits								
Biodiversity	High	High	High	High	High	Lack of data	Low	Low
Pollination	High	Medium	High	High	High	Medium	Low	Low
Pests control	High	High	High	Medium	High	Medium	High	Medium
Disease control	Medium	High	High	Medium	High	Lack of data	High	Medium
Weed control	High	High	Low	Medium	High	Lack of data	High	Medium
Soil health	High	High	High	High	High	Low	Low	Low
Soil erosion control	High	High	High	High	High	Low	Medium	Low
Nutrients availability	High	High	Medium	High	High	Medium	Low	Low
Water availability	High	Medium	High	High	High	High	Lack of data	Medium
Carbon sequestration	High	High	High	High	Lack of data	Medium	Low	Low
Resilience	High	High	High	High	High	Medium	Low	Low
Economic Benefits								
Yield	Low	Medium	Low	High	Low	High	High	High
Yield: stability	Low	High	High	High	High	High	High	High
Yield: longh- term effects	High	High	High	Lack of data	Lack of data	Medium	Medium	Medium
herbicides savings	Medium	Lack of data	Low	High	High	Lack of data	Low	Low
Pesticides savings	Medium	Lack of data	Medium	High	High	Lack of data	Low	Low
Ferilizers savings	High	High	Medium	High	Lack of data	Medium	Low	Low
savings in the use of machinery	High	Medium	High	High	Low	Low	Low	Low
labor saving	Lack of data	High	High	Medium	Low	Low	Lack of data	Low
Short-term risks	Low	Medium	Low	Low	Low	Lack of data	High	High
Long-term risks	High	Medium	High	High	High	Lack of data	Low	Low

Legend

- Low level
- Medium Level
- High level
- Lack of sufficient data

1.2 European public policy actions towards agroecology

The main challenge for the agricultural sector is to feed the growing world population while mitigating environmental impacts and conserving natural resources for the future (Vasylieva, 2018). As this sector can have a foremost effect on the environment the achievement of sustainable agriculture development is crucial for present and upcoming generations. European policies have been supporting the primary production sector for years with an ever-stronger awareness oriented towards sustainability.

As we have just seen in the previous paragraph agriculture can have negative impacts and positive impacts on environment. Agricultural systems are generally multifunctional and co-produce various goods including food for farmers and markets, but it also provides many public goods like preserve nature, clean air and water, flood protection, groundwater replenishment, carbon sequestration and delivers the landscaping services including leisure and tourism. Therefore, sustainability in agriculture can be considered as case- specific representing first an equilibrium between different agricultural and public goods (Piorr, 2003; Dobbs and Pretty, 2004).

As sustainable agriculture is oriented toward the usage of mostly natural goods, the innovative technologies and advanced practices need to be developed and locally adapted. This requires also new forms social capital, consisting of belief in relationships expressed in new organizations, new partnerships, and networking among institutional and human capital, incorporating leadership, resourcefulness, managerial and innovating capabilities (Olsson and Folke, 2001). Agriculture sector distinguished with high social and human capital is more capable of innovating and achieving Sustainable Development Goals (SDG) by ONU in current time full of uncertainties and risks (ONU, 2015).

Agricultural expansion and intensification are key drivers of biodiversity and ecosystem services loss as well as climate change (Díaz *et al.*, 2019). Historically some agricultural practices supported biodiversity and multiple ecosystem services. These processes are driven by socio-economic and technological forces but also supported by public policies (Pe'er *et al.*, 2020). Intensification of agricultural production in the past century across EU countries has seriously undermined the sustainability of the farming sector, resulting in widespread degradation of key environmental resources, such as land and water (Serebrennikov, Thorne and Kallas, 2020).

Nowadays, there are many agricultural policies, rural development plans, and concrete measures that help farmers improve the sustainability of their agricultural holdings (Moulogianni and Bournaris, 2021). The recognition of the limits of industrial production and its impacts on the environment has occurred in Europe for some time and is explicitly referred to in the current framework of the Community Agricultural Policy. In the European Union (EU), the Common Agricultural Policy (CAP) is the central policy for agriculture and could develop a large steering effect towards the above-mentioned issues if designed accordingly. Established under Article 38 of the Treaty on the Functioning of the European Union (TFEU) as a comprehensive subsidy system, the overarching objectives of the CAP have remained unchanged since its launch in 1962. Initially aimed at increasing the agricultural output through market price support, the CAP developed towards providing direct income support for famers since the 1980s.

In Europe, one of the first specific regulations on this topic coming from the early nineties when the European Community codified regulation Reg EEC 2092/91 on organic farming (European Economic Community, 1991). Immediately after, the accompanying measures of the CAP encourage the voluntary adoption of low environmental impact agricultural practices Reg. EEC 2078/92 (European Economic Community, 1992). A further action was the integration of the principles of eco-conditionality in the CAP, as well as a relaunch of policies aimed at multifunctionality in a context of rural development and re-orientation of the functions of agriculture in territorial management. The hectare-based payments have been made conditional on compliance with (basic) environmental requirements forming the first pillar of the CAP: market management and income support.

The recognizable awareness of the European legislator and of the main agricultural interest groups comes with the approval of Agenda 2000, an attempt at a pro-environment reform that recognizes the multifunctional character of agriculture, which has seen its full application with the Fischler reform in 2003. The reform introduced important tools such as environmental conditionality, through which aid was provided with the constraint of compliance with minimum environmental standards, food quality, animal welfare and efficient management of agricultural land. In the Community regulatory framework, the Reg. EU 1303/2013 must be mentioned. This defines the objectives and financial intervention instruments for the 2014-2020 programming cycle. The regulation aims to reduce the impact of agriculture on natural resources as well as to enhance the rural territory and its peculiarities (European Union, 2013a). Over the years there have been numerous reforms of the CAP and numerous actions that have led to an ever-higher increase in the agro-ecological value of the proposed policies. The following figure shows the main stages of the CAP reforms in which the promotion of agro-ecological principles has been strengthened (Figure 3).

Figure 3 – Main CAP steps timeline. (Source: adaptation from European Commission https://ec.europa.eu)

1.2.1 CAP: 1ST pillar policies that can "push" agricultural sector to agro-ecology.

Although the CAP has integrated environmental aspects, the environmental outcomes of this approach have been questioned on multiple fronts. Since 2013, to receive full payments under the first pillar, farmers must comply with cross-compliance which covers statutory management requirements (SMRs) and standards for good agricultural and environmental conditions (GAECs), and the requirements of 'greening'. However, cross-compliance only covers minimum requirements, and the environmental impact has been queried. 'Greening' goes beyond cross-compliance and requires crop diversification, the maintenance of permanent grassland and the establishment of ecological focus areas (EFA). Yet, 'greening' has been judged as environmentally weak, among others, because many farmers are exempted from the measure, and the requirements of EFA allow for a large range of areas to be considered as EFA. The proposal for a CAP beyond 2020 replaces 'greening' and cross-compliance with conditionality and introduces a new element: 'eco-schemes'.

The CAP has undergone several reforms, partly aiming to enhance its environmental and social performance. Some positive outcomes have been described (Batary *et al.*, 2015; Walker *et al.*, 2018), yet effective measures are required to reverse negative trends (Pe'er *et al.*, 2014, 2016) indicating the need of a much more fundamental change of the CAP to deliver on both environmental and socio-economic challenges. The European Commission has also included agroforestry as a practice in the Common Agrarian Policy (CAP), the main supporting tool for farmers in the 28 European Union countries (Santiago-Freijanes, Mosquera-Losada, *et al.*, 2018; Santiago-Freijanes, Pisanelli, *et al.*, 2018).

In this perspective, the new post-2020 CAP reform proposal is inserted. It has the main objectives to increase of sustainability in the agricultural sector, the mitigation of climate change and adaptation to these, the promotion of sustainable development with an efficient management of natural resources (water, soil, and air), the protection of biodiversity, the improvement of ecosystem services, habitats, and traditional landscapes. Improved sustainability in farming is one of the main objectives of the European Union's new Common Agri- cultural Policy (CAP) for 2021–2027 (Hannus and Sauer, 2021). Moreover, the key elements of the new CAP for the 2021 to 2027 period include a fairer distribution of direct payments, enhancing at the same time environmental and climate ambition, in harmony with the goals set in the European Green Deal (European Commission, 2019). Accordingly, the core component of the European Green Deal is the Farm to Fork Strategy aiming to make food systems fair, healthy, and environmentally friendly. The Farm to Fork Strategy (Euroepan Commission, 2020) was designed to encourage and speed the switching to a sustainable food system aimed at having a positive environmental impact (by reducing GHG emissions, adopting sustainable agricultural practices, and promoting the protection of biodiversity), ensuring food availability and safety, promoting fairy trade and a more equitable redistribution of profits.

The development of a framework for sustainable food labeling that covers the nutritional, climate, environmental, and social aspects of products is one the proposals under consideration. Furthermore, since 2009, the European Union carries on sustainable development policies through the EU Sustainable Development Strategy (SDS), and the Environmental Technologies Action Plan, whereas sustainable consumption and production (SCP) is the leading force of the Europe 2020 strategy designed to promote sustainable development (Lombardo, Farolfi and Capri, 2021).

According to the proposed Strategic Plan Regulation, 40 percent of actions of CAP beyond 2020 are ‘expected to’ contribute to climate objectives (European Commission, 2018a). The 40 percent share derives in part from the provision that 30 percent of the EAFRD funds shall be reserved for the specific environmental and climate-related objectives set out in Article 6 (1) (d), (e) and (f). Furthermore, Article 92 instructs Member States to make ‘a greater overall contribution to the achievement of the specific environmental- and climate-related objectives set out in points (d), (e) and (f) of Article 6(1) in comparison to the overall contribution’ in the period 2014–2020. According to Article 99 of the Strategic Plan Regulation, Member States will need to define annual planned outputs using a common set of output indicators of each intervention and define targets for each specific objective in accordance with Article 6(1) based on a common set of result indicators. The targets will be consolidated in a target plan and split into annual milestones. The common outcome, result and impact indicators are set out in Annex I of the proposed Strategic Plan Regulation. To avoid a ‘race to the bottom’ among Member States, robust EU-wide standards, and quantified objectives in the CAP beyond 2020 will be necessary when designing climate and environmental interventions. This specifically applies to the GAEC (good agricultural and environmental conditions) that Member States must implement nationally as well as the targets and annual milestones.

‘Eco-schemes’ are a proposed new element to the CAP, incentivizing environmental and climate action under the first pillar. The voluntary schemes for the climate and the environment are to be paid as annual payment per hectare. In general, payments should be granted either in addition to the basic income support or compensate ‘beneficiaries for all or part of the additional costs incurred, and income foregone as a result of the commitments as set pursuant to Article 65’. Article 65 of the proposed regulation concerns environmental, climate and other management commitments for rural development under the second pillar. Member States need to establish a list of practices which are beneficial for the environment, that according to Article 28(4) must meet at least one of the environment and climate-related objectives. Furthermore, while these measures promise to provide positive long-term impacts on biodiversity and climate and thereby contributing to the overall CAP objectives in addition to the ones related to the environment and climate (Article 6(d), (e) and (f)), funding for ‘eco-schemes’ is provided on an annual basis (Heyl *et al.*, 2020).

The new CAP reform adds an “Enhanced conditionality” for the new green architecture of the direct payments. Cross compliance makes obtaining CAP support conditional on beneficiaries' compliance with a set of basic rules on the environment, climate change, public health, plant health and animal health and welfare. According to a consolidated scheme, these basic rules include a list of Mandatory Management Criteria (SMR) provided for by Union law on health and the environment, and a series of minimum standards to be respected for the maintenance of Good agronomic conditions. and environmental aspects of land (GAEC). The set of these rules is, in fact, the basis of the green architecture of the CAP and the foundation for raising the level of environmental and climate ambition as requested by the Commission.

Ultimately the European Union has always pushed farmers towards the agro-ecological principles of cultivation. These actions have become increasingly concrete and restrictive and capable of converting “coupled payment farmers” to a new productive vision.

1.2.2 CAP: 2^{nd} *pillar policies that can "pull" agricultural sector to agro-ecology.*

The second pillar (rural development policy) meets the specific needs of rural development in each of the EU member states (Zolin, Pastore and Mazzarolo, 2019).

Under the second pillar of the CAP, Member States are required to devise multiannual national and/or regional programs which address the priorities of the pillar. Participation in the programs is voluntary for farmers, that is, a farmer receives income support of the first pillar but does not have to participate in programs of the second pillar. Among others, support is provided for agri-environment-climate commitments (AECs), for the conversion to or maintenance of organic farming and animal welfare commitments that go beyond mandatory standards. If well designed, programs have proven to have a positive impact on the environment for example by enhancing biodiversity.

The 'McSharry reforms' of the European CAP in the year 1992 first introduced obligatory Agri Environmental Schemes (AESs) to reduce negative effects of agricultural production on the environment (Lastra-Bravo *et al.*, 2015). Since then, the protection of environmental resources, such as soil, water, biodiversity, and climate, became increasingly important objectives of the CAP. In 1999, AES were embedded into the newly established Rural Development Programmes (RDPs) termed the 'Pillar II of the CAP', which generally aims at the development of rural areas (EU Council, 1999). The total EU RD budget for the recent programming period 2014-2020 to meet the RD aims amounts EUR billion 99.587 (24.4% of the total CAP budget). RDPs are periodical (programmed for a period of seven years), regionalized and voluntary for farmers to join. They are financed by the European Agricultural Fund for Rural Development (EAFRD) but in contrast to Pillar I of the CAP, also require co-financing by the Member States (MS). The three overarching priorities of RDPs in the recent programming period of 2014-2020 (European Union, 2013b, 2013c) were i) fostering agricultural competitiveness; ii) ensuring sustainable management of natural resources and climate action; and iii) achieving balanced territorial development of rural economies and communities, including the creation and maintenance of employment. Those main objectives were again grouped into six EU priorities for RD policy. The MSs have various options regarding the composition, design, and regional targeting of their individual RDPs; for the programming period from 2014-2020, this flexibility was even increased. There are 118 national and regional RDPs (20 single national programs and 8 MSs opting to have two or more (regional) programs). In their individual RDPs, the MSs can chose from a menu of 20 general RD measures (often again broken down into several sub- measures) to meet at least four of the six abovementioned EU-RD-priorities (European Union, 2013b, 2013c). The measures and sub-measures in the given menu of the EU Commission changed between each of the past three CAP-programming-periods (2000- 2006, 2007-2013, 2014-2020), but the main features and the range of measures remained largely the same. With the high variety and number of RD measures, very different impacts are induced on the economy, different sectors, and the environment. The most important possible impacts are changes in land use, productivity, environment, income, and employment (Schroeder, 2021).

The second pillar of the CAP will continue to offer a wide range of voluntary tools aimed at encouraging the adoption of practices oriented towards environmental sustainability and agro-ecology, mainly through surface payments. The tools available are described in art. 65 of proposed regulation on support for strategic plans (European Commission, 2018a) called "Environmental commitments, climate change and other management commitments ". The proposed actions, in fact, do not differ much from the types of intervention currently available. At the same time, some changes can be pointed out that will have important repercussions on the design and implementation of measures at national level. First, the proposal confirms the obligation for Member States to allocate at least 30% of the financial resources foreseen for the second pillar to environmental and climate actions. Payments for natural or other specific territorial constraints are excluded from this quota, as the connection of this type of support to environmental benefits is considered indirect. However, the European Green Deal establishes that "at least 40% of the overall budget of the Common Agricultural Policy and at least 30% of the Maritime and Fisheries Fund contribute to climate action" (European Commission, 2019). Beyond the expected expenditure, the main challenge concerns the need to adopt more innovative interventions than the current ones, because the strengthening of conditionality and the introduction of the eco-scheme, in fact, further raise the baseline for the interventions of the second pillar. In this regard, the proposal (in the article 65) raises the possibility for Member States to "promote and support collective schemes and performance-based payment schemes to encourage farmers to produce a significant improvement in the quality of the environment on a larger scale and in a measurable way " (European Commission, 2018a). Collective schemes could be particularly useful in favoring the agroecological transition on a territorial scale, as the successful experiences in Italy and in other countries testify how a collective approach in agro-environmental matters is able to stimulate a series of technical innovations, organizational and social that increase the effectiveness and long-term sustainability of the interventions (Vanni and Cisilino, 2017). Such schemes could also find effective implementation through involvement direct, and more active, of existing territorial entities.

So, among the most immediate tools available to the CAP to promote the adoption of the agroecological approach farm level there is certainly the Agri-environment-climate commitments (AEC) pertaining to the second pillar, suitably assisted by those of investment and service of transversal interest (training, counseling, cooperation, young people, risk management).

Increasing interest is being shown in result-oriented agri-environmental schemes (AES). Such schemes have the advantage of encouraging farmers to innovate to produce environmental goods thus promoting the development of new skills and knowledge and, theoretically, ensuring that farmers are paid for provision rather than for performing management behaviors that may, or may not, lead to provision. In Europe several projects have trialed result-based payments over the last decade and calls for a stronger connection between agri-environmental payments and outcomes are growing. So, the European Commission is developing the Results-Based Agri-environment Payment Schemes (RBAPS). Those payments are granted to beneficiaries only when a pre-established environmental goal is achieved. With the RBAPSs, not only are different methods of calculating the premium used, but in fact the concept of agri-environmental intervention completely changes. While the classic AES measures support and finance the adoption of certain agricultural practices that are believed to increase the environmental sustainability of production, with PBRAs the farmer is remunerated based on the environmental benefit he can produce, without being obliged to respect predefined production protocols.

Based on this evolution, the intention of the legislator is made clear, and the next step is being taken. The farmer will not just follow voluntary schemes to obtain payments but will be the protagonist and aware of seeing his farm sustainability increasing. Therefore, we can say that the CAP II pillar will continue to pull farmers towards agroecology in an ever more conscious way.

1.3 Agri-food supply chains and private initiatives for sustainability

In the context of the Agri-food System defined in 1977 by Malassis as "the set of activities that contribute to carrying out the food function of a given society", the agri-food chain constitutes a particular unit of investigation (Malassis, 1977). According to Saccomandi's definition, "the agri-food chain means the set of economic, administrative and political agents who, directly or indirectly, delimit the path that an agricultural product must follow to get from the initial stage of production to the final stage of use, as well as the complex of interactions of the activities of all the agents that determine this path "(Saccomandi, 1991). At the end of the nineties the concept of the agri-food chain is flanked by that of the Supply Chain which was defined by Christopher in 1992 as the network of organizations involved, through links with a “mountain” and a “valley”, in the different processes and activities that value in the form of products and services for the end customer (Garavelli, 2003). Within the agri-food supply chains, networks are established that involve many actors including farmers, feed and seed producers, resellers of technical means, breeders, transporters and distributors, traders and consumers who assume a key role through the choice of a specific product.

The producers of raw materials, in many cases, however, tend to use intensive and monospecific agriculture methods, thus modifying the territorial structure in which they operate. The choice to operate in this mode is to be read not only as a response to the requests of the supply lines of large agro-industries, but also as a combination of technological needs and the conversion of traditional and diversified systems into specialized systems that have involved agriculture, in especially the European one, from the end of the 1960s to today. Has we have seen, the evolution of the CAP has followed the social demands linked to the primary sector, first focused on the production of food, then on safeguarding the incomes of their farmers and as mentioned, starting from the 2000s on the enhancement of the multifunctionality of agriculture (compare 1.2).

A particular type of supply chain that has recently been growing in the agri-food sector is the short supply chain. These are characterized by their alternation with respect to traditional supply chains, in which at least three subjects are involved in which the wholesalers (buyer) often represent a fundamental pawn. In fact, the so-called “Alternative Agri-Food Networks” take their name from the rejection of the main characteristics of traditional supply chains, such as extreme productivity, standardization, and industrial organization (Higgins, Dibden and Cocklin, 2008). The aim of those networks is to take better care of other aspects such as the quality, origin, and "naturalness" of agri-food productions (Goodman, 2003). Short supply chains are characterized by the absence of intermediaries between producers and consumers and, moreover, by the local dimension of production, processing and marketing (Renting, Marsden and Banks, 2003). In the new sustainable agriculture, the agri-food supply chains therefore play a strategic role in promoting economic development, offering consumers quality products that respect the environment and the territory (Mangla *et al.*, 2018).

However, the actions of the agri-food supply chain, not only understood as a short or alternative supply chain, in support of the respect and maintenance of the European and national landscape and of biodiversity, can be guided by private standards that lead to certification, or to the recognition by the consumer of an otherwise unrecognizable attribute of sustainability. The labelling and communication to the consumer of a conscientious approach in the agricultural production phase is now sought by not only small and traditional food producers. The added value connected to the affixing of a claim that refers to sustainability on the packaging of the products has led various agro-industries to invest in certification and in the definition of innovative business models capable of guaranteeing supplies of "sustainable" raw materials over time.

A first approach consists in using raw materials certificated by sustainability certification schemes. Recently agro-industries have promoted others approaches based on private sustainable supply chain initiatives, and they have started communicating sustainability-claim related information about food to consumers, introducing labels and logos in-store and on-pack.

1.3.1 Certifications schemes

In the case of agricultural products producers may view a quality certification (either it is a certification of traceability or a quality label) as a tool that protects them in an environment of distrust and as a promotion strategy that will add value to their products and justify higher prices for them. However, for value-added markets to be successful an effective communication must be promoted (Botonaki *et al.*, 2006). Agro-food firms choose consumer value creation for differencing final product adding multiple attributes designed to meet an increasingly segmented and personalized consumer demand (Sanz Cañada and Macías Vázquez, 2005).

Systematic quality assurance and improved traceability are considered cornerstones for improving the competitiveness of European agribusiness (Bogetoft and Olesen, 2002; Theuvsen and Hollmann-Hespos, 2005). One further driver of the implementation of certification procedures is the huge importance of certificates if a supplier wants to deliver to large retailers such as Aldi, Carrefour, Tesco and Metro. This makes the implementation of a scheme such as the International Food Standard (IFS) obligatory (Theuvsen and Plumeyer, 2007; Schulze *et al.*, 2008).

Furthermore, the European Union is encouraging this trend through legislative actions such as the introduction of EU-wide certification systems, as in the organic farming sector; the Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) systems; the establishment of European food safety agencies; and strict regulations on food safety and hygiene (Gawron and Theuvsen, 2009).

Standards enable the state to regulate in a less costly way since the enforcement of regulations is outsourced to private actors (Henson and Reardon, 2005; O'Rourke, 2006). Firms embrace standards to manage supply chain risks, ensure conformity among all suppliers, limit competition and transaction costs, or gain competitive advantages (Ponte and Gibbon, 2005). Civil society actors use standards to advance their interests as consumers or activists (Murray and Raynolds, 2000; Dimara, Petrou and Skuras, 2004). Beyond these ‘‘interest-based’’ explanations, an increasing number of studies focus on standard-setting processes. Some see their private nature and their inclusiveness as important conditions to ensure the efficiency and legitimacy of the initiatives (Boström, 2006; Bernstein, 2011).

Standards like Rainforest Alliance, UTZ Certified, or even GlobalGAP increasingly point to sustainability arguments in their legitimating discourses (Fouilleux and Loconto, 2015). The most common model of certification is ‘‘third-party,’’ where certifiers are private actors, independent; they are paid by the farmers to control their practices, and release a certificate of conformity to the standard. However, the origin lies with the use of other models of certification, now referred to as ‘‘first-party’’ (where private individuals or groups self-declare their compliance with a standard) and ‘‘second-party’’ certification (where an organization to which the controlled entity belongs provides the assurance). For organic products in EU the multi-layered market structure of the tripartite standards regime of governance (standard-setting, certification, and accreditation activities), links to a layering of markets for services that are additional to (and inseparable from) the market for certified organic products.

Addressees of the certificates can be either other businesses, consumers or – in some cases – both. Business-to-business (B2B) standards are not communicated to the final consumers, who are often unaware of their existence; GlobalGAP, the International Food Standard and the ISO 22000 are all B2B standards. B2B standards seek to reduce quality uncertainties in food supply chains and, in that way, serve as quality signals, reduce transaction costs and liability risks and favour spot-market transactions (Schulze, Achim and Theuvsen, 2006) Business-to-consumer (B2C) schemes address the final consumer, typically by displaying a logo on the products produced by certified farms and firms (Freedom Food, Label Rouge). B2C standards represent the majority of certification schemes in the EU, but they often (although not always) operate in market niches (Gawron and Theuvsen, 2009).

Certification schemes can have very diverse objectives, which can be roughly described as the improvement of food safety by guaranteeing compliance with minimum standards and differentiating food products. Minimum standard schemes reduce quality uncertainties, especially about credence attributes, such as freedom from microbiological risks. Often these schemes systematically compile legal rules, norms and industry guidelines (such as good hygiene practices), but largely refrain from defining higher standards. Enforcing compliance with minimum standards is typical of many B2B schemes, such as the BRC Global Standard, GlobalGAP and the International Food Standard. Ferrucci proposes in his book a review of the major certifications used by the agro-industry to ensure / transmit quality at every level of the supply chain (Ferrucci, 2020). The increase in sustainability that the product can bring to the system is fully part of the concept of quality.

With the aim of differentiating the product, different types of certifications insist on the market that looks at environmental and social issues oriented towards the sustainability. Some standards incorporate them, others are totally dedicated. The following table schematically summarizes the standards most used by the agro-industry to purchase raw materials and promote pro-environment and pro-agroecological actions (Table 5). The certification schemes reported have been evaluated for their correspondence to the main themes of agro-ecology proposed by FAO (cf. 1.1.1): in the last column for each item the main elements of correspondence have been reported.

Table 5 – Sustainability standards most used by the agro-industry and their correspondence to the main themes of agro-ecology proposed by FAO. (Source: own elaboration)

Certification scheme	Logo	Normative requirements / References	Main requires and objectives	Elements of agroecology by FAO
Organic		Reg. (EC) 834/2007 Reg. (EC) 889/2008 Reg. (EU) 2016/673 Reg. (EC) 1235/2008 Reg. (EU) 2020/25 Reg. (EU) 2018/848	The objectives identified by art. 3 of Reg. (EC) 834/2007 provide that the organic production must: a) establish a sustainable management system for agriculture that: - respect natural systems and cycles and maintain and improve the health of soils, waters, of plants and animals and the balance between them; - contribute to a high level of biological diversity; - ensure responsible use of energy and natural resources such as water, the soil, organic matter and air; - meets strict animal welfare criteria and meets - the specific behavioural needs of the animals according to the species. b) aim at obtaining high quality products; c) aiming to produce a wide variety of food and other agricultural products that respond to consumer demand for products obtained with processes that do not harm the environment, human health, plant health or animal health and welfare. General principles see organic production based on: - planning and appropriate management of biological processes - they use living organisms and mechanical production methods - practice the cultivation of vegetables and animal production related to the land - exclude the use of GMOs and products derived or obtained from GMOs - limitation of the use of external production factors. Use of: production factors from organic production; natural substances or substances derived from natural substances; low solubility mineral fertilizers;	Diversity Resilience Efficiency Synergies Recycling Sharing Of Knowledge Responsible Governance Human And Social Values
SQNPI Sistema Qualità Nazionale Produzione Integrata *Italy*	SQNPI QUALITÀ SOSTENIBILE SISTEMA DI QUALITÀ NAZIONALE PRODUZIONE INTEGRATA	Reg. (CE) 1698/2005 Italy - Legge n. 4 del 3 febbraio 2011 Italy - Decreto Ministeriale 8 maggio 2014 References to regional technical standards: https://www.reterurale.it/produzioneintegrata	The cardinal principles of the SQNPI are carefully balanced between the production system (the balanced nutrient cycle, crop protection and distribution of crop protection products) and environmental protection (the central role of agroecosystems). Specifically, it is possible to summarize them as follows: - Defense and control of weeds - Choice of cultivation environment and suitability - Maintenance of the natural agro-ecosystem - Variety choice and multiplication material - Soil arrangement and preparation for planting and sowing - Crop rotation - Sowing, transplanting, planting - Soil management and agronomic practices for weed control - Fertilization - Irrigation - Other production methods and particular aspects	Diversity Efficiency Resilience Synergies Sharing Of Knowledge

UNI 11233	**UNI 11233:2009**	UNI 11233 Integrated production systems in agri-food chains - General principles for the design and implementation in the vegetable supply chains (ed. 2009)	The standard establishes the general principles for the design and implementation of integrated production systems in the vegetable supply chains. These are defined by the law as "agricultural production systems that favor the use of natural resources and regulation mechanisms in partial replacement of chemicals, ensuring sustainable agriculture". They are therefore subject to careful evaluation: the production system as a whole; the central role of agroecosystems; a balanced cycle of nutritional elements. The constituent elements must be formalized in a specification technical and are identified in the following aspects: - Pedoclimatic vocation - Choice of variety and rootstocks - Maintenance of the natural agro-ecosystem - Soil arrangement and preparation - Sowing, transplanting, planting - Crop rotation - Soil management and weed control - Management of fruit trees - Fertilization; Irrigation; Crop protection; Distribution of crop protection products - Post-harvest protection	Diversity Efficiency Resilience Synergies Sharing Of Knowledge
GLOBAL G.A.P.	GLOBALG.A.P.	Global G.A.P. General Rules Part I - General Requirements. Global G.A.P. General Regulations Part II - Regulations of the Quality Management System.	Responds to market expectations regarding the safety of food products for the vegetable, livestock, and feed chains. The field of application of the GG Standard is the primary sector, specifically the three main areas of production: cultivation, breeding and aquaculture. The goal of the GG Standard is to provide safe food through evidence of the continuous adoption of "Good Agricultural Practices" throughout the entire agricultural production chain, from the countryside to the point of sale. The cardinal principles of the GG Standard are summarized in four points: 1. Legitimacy of the production system 2. Competence 3. Protection of workers 4. Environmental Protection	Efficiency Synergies Sharing Of Knowledge Human And Social Values Responsible Governance
ISO 14001	**Environmental Management System ISO 14001**	UNI EN ISO 14001 Environmental management systems	The standard is intended for an organization that wishes to manage its environmental responsibilities in a systematic way and which contributes to the environmental pillar of sustainability. Consistent with the organisation's environmental policy, the expected outcomes of an environmental management system include: - the achievement of environmental performance; - the fulfilment of compliance obligations; - the achievement of environmental objectives It does not establish any specific criteria of environmental performance. The standard can be used, in whole or in part, to systematically improve environmental management. The standard aims to help an organization achieve the expected outcomes of its environmental management system in order to provide value for the environment.	*Defined at farm level.*

ISO 46001	**Water efficiency management ISO 46001**	ISO 46001 Water efficiency management systems - Requirements with guidance for use	By establishing a framework and providing guidelines on water efficiency management, the ISO 46001 standard provides methods and tools for assessing and accounting for water consumption, as well as guidance on how to identify and implement measures to optimize water consumption. It refers to Goal number 6 of the 2030 Agenda for Sustainable Development of the United Nations.	Efficiency
Fairtrade	FAIRTRADE ®	FLOCERT is the leading independent certification body for Fairtrade (www.flocert.net)	The criteria adopted by the standard are: a) Economic criteria: Guaranteed Fairtrade Minimum Price; Fair Trade Award, for farmers and workers who invest to improve the quality of their life and work; long-term business partnerships and pre-financing. b) Environmental criteria: Good agricultural and environmental practices; Respect and maintenance of biodiversity and soil fertility; Reduction in the use of pesticides and pesticides; No OGM. c) Social criteria: small producers organized in a democratic way and must follow participatory, transparent, and inclusive decision-making processes; companies must hire on a non-discriminatory basis, pay wages equal to or higher than the legal or local minimum wages, ensure freedom of association and collective bargaining for employees, safeguard workers' health and enable them to manage the Fairtrade Award; forced labour and child labour are prohibited.	Resilience Efficiency Synergies Recycling Responsible Governance Human And Social Values Circular And Solidarity Economy
SA 8000	ETHICALLY CORRECT CERTIFIED COMPANY SA 8000	Guidance document for social accountability 8000 (SA8000®: 2014). Source: www.sa-intl.org	The SA 8000 standard is based on the conventions of the ILO (International Labor Organization), the Universal Declaration of Human Rights and the United Nations Convention on the Rights of the Child. Social requirements aimed at increasing the competitive capacity of those organizations that voluntarily provide a guarantee of the ethics of their production chain and production cycle. Nine key points: - Child Labor; - Forced labor; - Occupational health and safety; - Freedom of Association and Right to Collective Bargaining; - Discrimination; - Disciplinary measures; - Working hours; - Remuneration; - Human Resources Management System	Human And Social Values Responsible Governance Circular And Solidarity Economy

Carbon Footprint LCA ISO series 1406X/14040	demonstration image: the standard does not define a specific logo	ISO 14064-1 ISO 14064-2 ISO 14064-3 ISO 14067 ISO 14040	In general, the term "Carbon Footprint" refers to an environmental indicator, the measure of which is expressed in tons of CO2 equivalent. The carbon footprint therefore expresses the totality of GHG emissions (Greenhouse Gases - greenhouse gases) calculated with a technical "life cycle" approach for as specific product. The purpose of the standard is to establish the environmental impacts that emissions have had on the ever-changing climate, to encourage environmental sustainability against climate change. *Product Carbon Footprint (ISO 14067 - CFP)* Expressed in the CO2eq unit of measurement, the Product Carbon Footprint (CFP) considers the overall emissions of all phases of the life of the product / service "from cradle to grave", compared to the Global Warming Potential of CO2 *Carbon Footprint of Organizations (ISO 14064)* The ISO 14064 standard is composed of a family of standards specifically aimed at: - quantification and reporting, - reduction and absorption, - validation and verification of voluntary assertions (declarations) relating to greenhouse gas emissions of organizations. By "Organizations" it is possible to mean both companies or supra-company organizational structures (such as holding companies, groups, etc.) but also, in a broader sense, individual construction sites, production sites, tenders, etc. The standard referred to in ISO 14064 is made up of three parts: - 1 -2 – 3 -4.	Efficiency Synergies Recycling Responsible Governance
Water Footprint ISO 14046	demonstration image: the standard does not define a specific logo	ISO 14046	The Water Footprint of a product is defined as the total volume of fresh water used directly and / or indirectly to make the product itself, evaluated considering the use of water in all phases of the production chain throughout its cycle of life. The Water Footprint Assessment is developed in three phases: - quantification and localization of the water footprint of a product or process in the reference period; - assessment of the environmental, social and economic sustainability of the water footprint; - identification of the reduction strategies of the same.	Efficiency Recycling
ISCC PLUS		Requirements and checklist on www.iscc-system.org.	ISCC PLUS is a certification system for sustainability, absence of deforestation and traceability of: - Agricultural and forestry raw materials - Agricultural and forest crop residues (husks, straw) - Waste, industrial residues (crude glycerin, tall oil, landfill gas, municipal solid waste, mixed plastic waste, end-of-life tires) - Renewable raw materials of non-biological origin (power to gas, power to liquid, CO2) - Recycled products - Fuels derived from recycled carbon used in the following supply chains: food, feed, biochemistry, and bioenergy.	Efficiency

1.3.2 Private standards and initiatives: focus on bakery Italian scene

The widespread use of private standards within an increasingly competitive global food system, where flexibility, efficiency and rapid responsiveness is key to success, highlights the intricate of supply and demand relationships between different portions of the supply chain. They essentially aid in the governance of the food system across regions and sectors Those who do not meet the standard may be excluded from markets in the short run and may eventually be forced to exit the sector. This consequence may be important for small and medium firms/farms, which are often unable to meet the stringent technical conditions imposed by the food chain. But, private standards may also provide incentives for physical and human capital development in order to raise technical competencies, leading to future market access and earnings.

In recent years, numerous companies in the Italian agri-food sector have undertaken new policies in the direction of sustainability. Looking mainly at the supply chains that use arable land to produce raw materials for the food sector industries operating in the flour, bread and sweets market, it is possible to mention a few including: the Barilla company that will be the subject of the case study of this thesis, followed by the Galbusera brands and the multinational Mondalez with the Italian brand SAIWA.

The Italian company Galbusera, a manufacturer of biscuits and crackers, has recently launched a sustainability project called the "Filiera Grano Tenero Italiano"[1] based on the goals of the 2030 Agenda, which plans to use only 100% Italian wheat. The project envisages a supply chain made up of farmers, stockers and mills with wheat grown in the Piedmont, Lombardia and Emilia Romagna regions, implementing a selection of the best varieties. "Filiera grano tenero Italiano" proposes the adoption of sustainable cultivation practices including oases of flowers and plants to attract pollinating bees and insects, a reward for the players in the supply chain and data collection on a single platform.

The objectives of the Italian brand Saiwa, specializing in the production of biscuits, crackers, and chips, are to guarantee a reduction in the environmental impact

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[1] For much information: https://www.galbusera.it/filiera-grano-italiano/

and an increase in sustainable raw materials by 2020 through initiatives such as "Harmony, il patto del grano buono"[2]. Harmony is a sustainable wheat cultivation program that arises from a pact with local farmers who are encouraged through a system of awards to respect the sustainable agricultural practices contained in the program by maintaining the use of pesticides and fertilizers, protecting water and soil and reducing the carbon dioxide emissions. The program also includes specific practices for the enhancement of biodiversity such as the use of 3% of the land for the cultivation of flowers or trees to attract and feed bees and butterflies.

The initiatives just mentioned are all examples of programs adopted by large companies and industries producing necessities that in recent times increasingly seek to direct their production towards a sustainable and ecological line, implementing agricultural practices that aim to enhance both the product than to minimize the environmental impact and at the same time seek real collaboration and partnership with farmers. The track made by the agro-industry is therefore quite clear: integrate the supply chain and make it sustainable starting from contact with primary producers and trying to sensitize both them and consumers in a logic that aims at the agro-ecological transition.

[2] For much information: https://harmony.info/it-it#partnership

CHAPTER 2
CASE STUDY DEFINITION

The purpose of this chapter is to illustrate the research question and the context in which it arose. Then follows a description of the identified case study and the context in which it develops.

2.1 Aim of this work and case study selection.

In a context in which several entrepreneurs voluntarily decide to invest in initiatives based on sustainability, it is interesting and important to understand the influence of agroecological practices and principles both in an environmental and economic dimension. From the environmental point of view, it is now clear based on the analysed literature, that through the application of agro-ecological or agri-environmental practices in intensive production contexts, an environmental benefit is obtained that goes to support the community. However, what is asked is which subject is called to pay this benefit generated since the price of the final product does not change while changes are required, which often involve higher costs, to primary producers.

Certifications often allow farmers to enter a different market. This market values products with higher withdrawal prices. But also, are often used as a “barrier” to supply: if the product complies with the standard it is purchased by the agro-industry; if it is not the farm does not enter the supply chain. Farms are already involved in a system that tends towards agro-ecology dictated by the European public policies of the sector. These policies encourage the transition to agro-ecological practices in several ways, trying to reduce the impacts that intensive agriculture has on the whole national territory. Political actions foresee a contribution paid for the efforts to which farmers are subjected. The amount of the premium varies according to the actions taken by the farmer. Almost all the private initiatives such as those previously mentioned provide for a first prize from the promoting company, to encourage more and more operators in the supply chains, producers and first processing companies, to adopt these different production programs.

In this perspective, the research question that prompted the realization of this thesis project arises. Understanding how effectively the supply chain can create synergies between the actors involved, by researching and experimenting a replicable and adaptable methodology that can be used in any context of agricultural production. So, relating to the figure 1 (cf. Introduction) identify economic impacts of public policies and private initiatives and how those can “pull”, or “push” the case study’s farms to diversify their cropping systems in compliance to the main agro-ecology principals. Understand how much this shift can create costs or benefits for the farms and identify the extent of the same. Therefore, looking at the entire supply chain, we want to try to understand if this system of rewards (public and private) is sufficient for the greater efforts that all or some of the players support to adapt to these new production methods.

As shown in the first part of the review, there are different types of farms and agricultural contexts, ranging from small to industrial scale, and consequently the effects of adopting agroecological practices differ according to the contexts in which they are implemented. At the same time, the current market and supply chains require increasingly sustainable products and therefore the need for farms to comply with these standards arises. So far, agroecological strategies and practices have been seen to be advantageous and can represent valid alternatives for companies located above all in developing contexts (Pretty et al., 2006). However, one wonders how to achieve this goal for all those who do not possess these characteristics (medium and large farms). Understand what the barriers could be encountered by a type of farm that does not fit into the small scale but in a highly industrialized context and that decides to join pro agroecological private actions because they are required by specific agro-industrial chains. It is therefore good that the agricultural reality in which these questions are asked is contextualized: large farms, which are placed in a classic context of agro-industrial supply chain. So, is of great importance that the strategies implemented to promote the agroecological transition are successful and profitable from an economic point of view. The demonstration of this positive impact could allow the adoption of these practices by a substantial number of actors in the supply chain. In order to maintain this over time, it is good to consider the economic sphere of the operators in the supply chain even in the medium-long term, verifying that they do not have substantial losses in profitability over time.

At the same time, it is of great importance to evaluate the current strength of public initiatives in which farms highly specialized in the production of arable land commodities adhere. The current public initiatives dictated by the CAP, in a context of specialized production on the production of arable land, condition the choices of the farmer. As illustrated in chapter 1, there are numerous pro-agroecological constraints imposed by the legislature to access first and second pillar funds (Cf. 1.2). The aim is therefore to evaluate the importance of these practices both from an economic point of view and in terms of diversification of the context in which highly specialized farms are present.

To try to answer these questions and propose a methodological strategy that can be replicated in the major production contexts, it was decided to identify the case study on a private pro agroecology initiative that is part of a highly industrialized Italian agricultural context: the "Carta del Mulino" initiative promoted by Barilla.

2.2 Case study identification: the “Carta del Mulino” private initiative.

During the analysis of the main private certification schemes adopted by the agro-industry, the collaboration of the DIBAF department in the "Carta del Mulino" project promoted by Barilla played a fundamental role. The "La Carta del Mulino" initiative is the result of a project concerning the production of soft wheat flour, carried out by the Barilla Group and in collaboration with WWF Italy, University of Bologna, University of Tuscia and Open Fields.

Mulino Bianco® is one of the most important Italian bakery brand managed by the Barilla food company. Since 1975, Mulino Bianco has characterized its communication strategy telling naturalness’ icons and carefulness messages about environment and people. In 2017, it launched the “Buongrano” initiative, where the main goal is to increase the biodiversity in agricultural land, in order to obtain within 2020 all supply raw materials certified as “sustainable”, following the general company sustainability strategy. To achieve these goals Mulino Bianco requires to millers, cereal elevators and farmers to reach the compliance to ten rules, following production private standard called “Carta del Mulino”[3] (CdM).

The standard consists of ten rules drawn up and designed to bring greater quality to products, to support the work of farmers and to restore space to nature in agroecosystems, promoting biodiversity, reducing the use of chemicals, and safeguarding pollinating insects. The proposals presented by the project fall within the practices and principles of transition towards agroecological systems and aim to preserve the structure of the soil and increase its fertility, promote the crop diversification, promote the optimal wheat varieties to guarantee products of a higher quality. The final objective of the project is to make the cultivation and transformation of soft wheat sustainable for all Mulino Bianco brand products, promoting virtuous agricultural practices for environmental protection, involving all the players in the supply chain with an assessment of the compensation of the economic value of the commitments required, to also ensure economic and social sustainability.

Going into detail, the ten rules proposed in the last version of the initiative are reported below:

1. *ISCC PLUS.* All the actors of the "Carta del Mulino" must comply with the requirements of the ISCC PLUS (International Sustainability and Carbon Certification) sustainability certification. The ISCC PLUS certification (International Sustainability and Carbon Certification) is an internationally recognized standard based on elements that preserve the biodiversity of natural resources, helping to implement the levels of sustainability and traceability of the supply chain (cf. Table 5). Verification of this certification, as well as compliance with the requirements of the "Carta del Mulino", takes place through an audit by an independent third-party Control Body.
2. *Crop rotation*. All farms must adopt, with reference to the "Carta del Mulino" soft wheat parcel and starting from the agricultural year of accession to the project, a rotation plan that includes: five years of crop rotation with three different crops

[3] For much information: https://www.mulinobianco.it/lacartadelmulino

(in the five-year period) including, compulsorily, at least one legume and / or oilseed; only 1 year of replanting of the same crop.

3. *Flower strips*. Destination by the farms of part of their arable land to cultivate areas with a mix of flowering plants ("Fiori del Mulino") composed of legumes and other nectar species. The flowered areas can be permanent or temporary with dimensions equivalent to 3% of the UAA (Utilized Agricultural Area) with “Carta del Mulino” soft wheat.
4. *Certified seeds*. All farms must use only certified seeds and the varieties indicated by Barilla for the cultivation of soft wheat. The varieties indicated in the list possess the qualitative and rheological characteristics required by the processing standards of Mulino Bianco. The use of genetically modified plant material is prohibited.
5. *No neonicotinoids*. All farms must not use seeds tanned with neonicotinoids and / or phytosanitary products also containing neonicotinoids for sowing the "Carta del Mulino" soft wheat parcel, even in countries where it is permitted by the respective national regulations.
6. *No purification Sludge*. All farms, with reference to the “Carta del Mulino” soft wheat parcel, must not use purification sludge starting from the cultivation term of the species in precession and / or before the soft wheat, up to the final phase of the harvest. By purification sludge we mean the residues deriving from the purification processes of wastewater from civil and production settlements.
7. *No Glyphosate*. All farms must not use glyphosate and / or plant protection products also containing glyphosate in the “Carta del Mulino” soft wheat parcel from pre-sowing to harvest. By "pre-sowing" we mean a period of 60 days before sowing.
8. *Segregation and traceability.* All the adherents to the "Carta del Mulino" must: guarantee separate collection and delivery of the soft wheat batches coming from the plots involved in the project; ensure the segregation of the batches of soft wheat and flour belonging to the project.
9. *Conservation*. All members must use only one or more of the following cereal conservation techniques during the storage of the batches of soft wheat and flour

belonging to the "Carta del Mulino": physical methods; methods allowed in organic farming; methods based on synthetic pyrethroids including adjuvants.

10. *Transfer of value.* All the adherents to the "Carta del Mulino" must guarantee an economic recognition distributed along the entire supply chain. This value must be specified in the contracts between the parties adhering to the percentage or absolute value of the reference price present in the contracts.

To be able to monitor and declare the action for sustainability, the Barilla purchasing group, owner of the Mulino Bianco brand, signs a contract for the supply of flour from sustainable agriculture (in compliance with the rules of the Carta del Mulino) with the mills that a in turn they must provide the supply with a contract with their common wheat which can be stockholders, farms or any aggregation of agricultural producers or traders. Barilla uses several mills responsible for transforming wheat into flour and present both in Italy and in European countries. Looking at the national context, the mills procure grain from storage centres located in various provinces of northern and central Italy. Each contract must be registered, and its characteristics reported in a portal created by Barilla in which the documents necessary for the certification body are stored to provide audits and verification of compliance of the productions with the standard. An independent Certification Body certifies the compliance with Carta del Mulino rules and ISCC+ certification along the production chain.

The Cdm rules are based on strong agroecology principals: promote the crop diversification and the polycultures whit a large crop rotation and by using nitrogen fixers crops; promote the polycultures and the diversification with the flower strips; promote the economic well-being with the business tool identified by the agro-industry. According to the "Carta del Mulino", the adoption of the proposed crop rotation could preserve the soil structure (stability, less erosion, greater efficiency in the use of water), increase its fertility (better productivity without the use of synthetic fertilizers), reduce the presence of specific pathogens by increasing the resistance of the crop to parasitic diseases and weeds and finally allowing economic savings for the farmer and better protection of the environment. The flower strips called "Fiori del Mulino" are areas of ecological interest sown with a mix of herbaceous plants appropriately selected to increase the biodiversity of the agroecosystem. Through the support of the WWF and the Alma Mater University of Bologna, these strips have been designed to act as ecological corridors and habits suitable for the proliferation of pollinating insects and natural predators of parasites from nearby crops. The experimentation already conducted by Alma Mater University of Bologna has confirmed that the introduction of a mix of flowering plants has overall increased the biodiversity of the companies examined, increasing the percentage of flowering essences and the number of apoidea and lepidoptera, as well as attracting predatory insects and parasitoids, natural antagonists of aphids, (the main phytophagous of wheat) which could allow to limit the use of insecticides. In the case of temporary bands, the plants present are left in the field and buried at the end of the cycle (green manure) so that their natural degradation returns organic substance to the soil, resulting in an improvement in both physical and chemical fertility.

So, the agro-ecological value of the actions of the proposed case study turns out to be significant. The actions of crop differentiation (crop rotation and flower strips) are of great importance from the agro-ecological point of view, but they are also those that incur the greatest transition costs in adopting this production scheme. Rule ten, also in full agro-ecological principle, provides that the primary producer is rewarded for the effort with a premium price. For these reasons, the whole initiative lends itself perfectly to being taken as a case study for this work. The following table (table 6) shows the convergence between the ten rules of the Cdm private initiative, and the ten elements of agro-ecology proposed by FAO (cf. 1.1).

Table 6 – The ten rules of the "Carta del Mulino" and their correspondence to the main themes of agro-ecology proposed by FAO. (Source: own elaboration)

Cdm rules N°	**Cdm rules Key words**	**Elements of agroecology by FAO**
1	ISCC PLUS certification	Efficiency
2	Crop rotation.	Diversity, Resilience, Efficiency
3	Flower strips	Diversity, Resilience, Efficiency, Synergies
4	Certified seeds	Efficiency
5	No neonicotinoids	Diversity
6	No purification Sludge	
7	No Glyphosate	Diversity
8	Segregation and traceability	
9	Conservation	
10	Transfer of value	Responsible Governance, Human And Social Values

2.3 The production context of the Italian supply area.

The case study considered finds the greatest adhesions in the Italian context in the Po Valley, in the regions that fall within the designated area, that are Emilia Romagna, Lombardia, Piemonte and Veneto. The following maps shows distribution of farms, involved in the Carta del Mulino project in the Po Valley from the year 2018 to the year 2021 (Figure 4, 5, 6, 7). As we can see, starting from 2018, first year of project, we found great evolution in number of farms involved in the project located in the Po Valley.

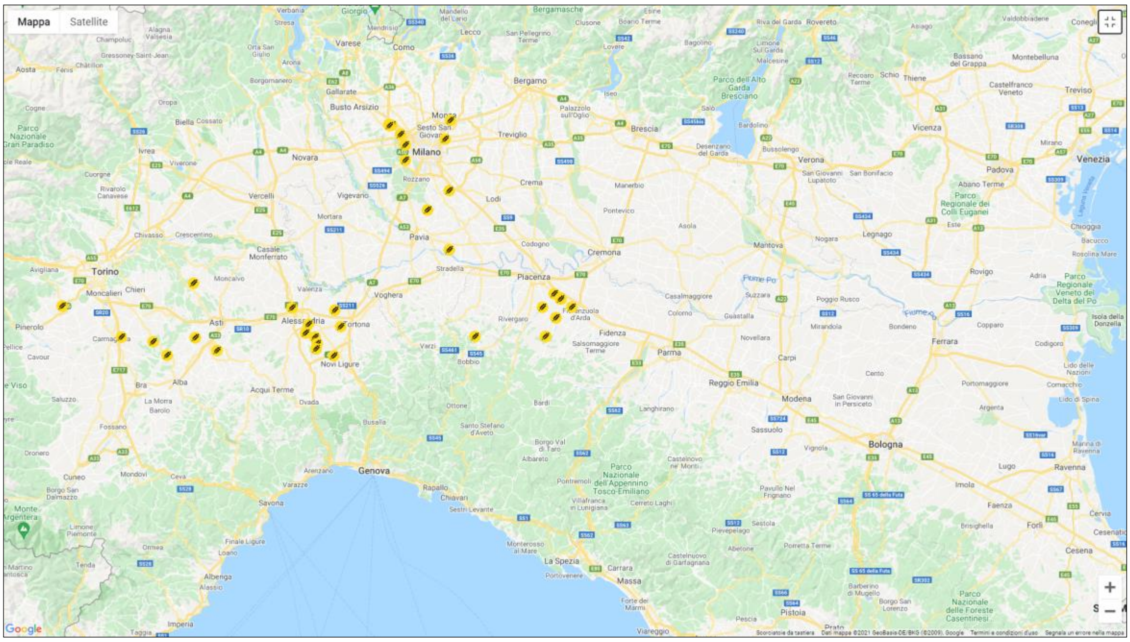


Figure 4 - Farms involve in Carta del Mulino 2018. (Source: https://www.mulinobianco.it/lacartadelmulino)

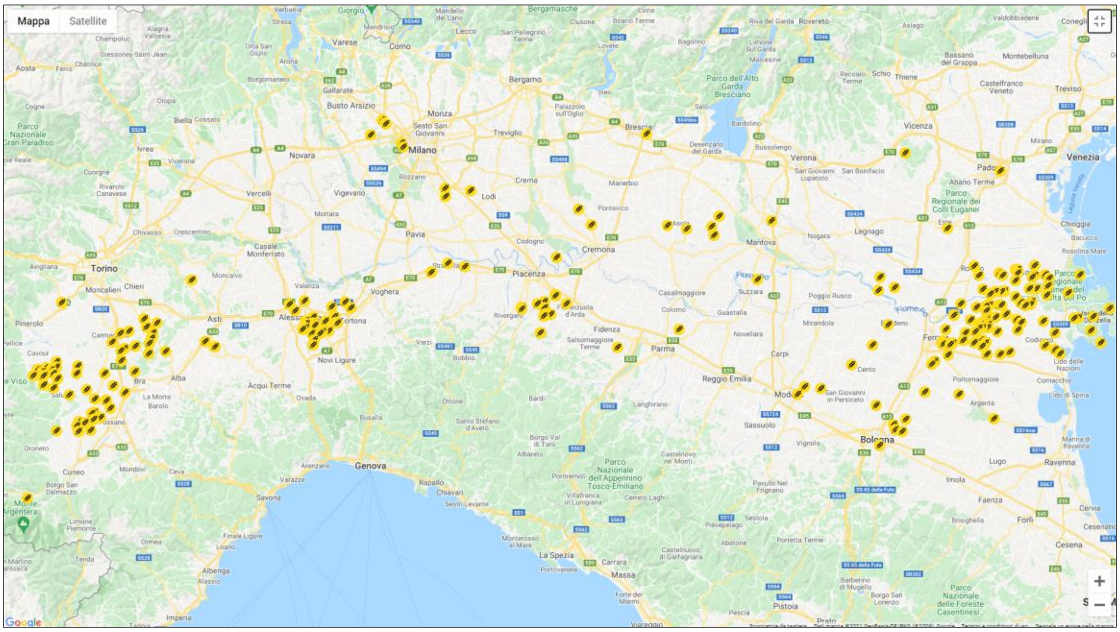


Figure 5 - Farms involve in Carta del Mulino 2019. (Source: https://www.mulinobianco.it/lacartadelmulino)

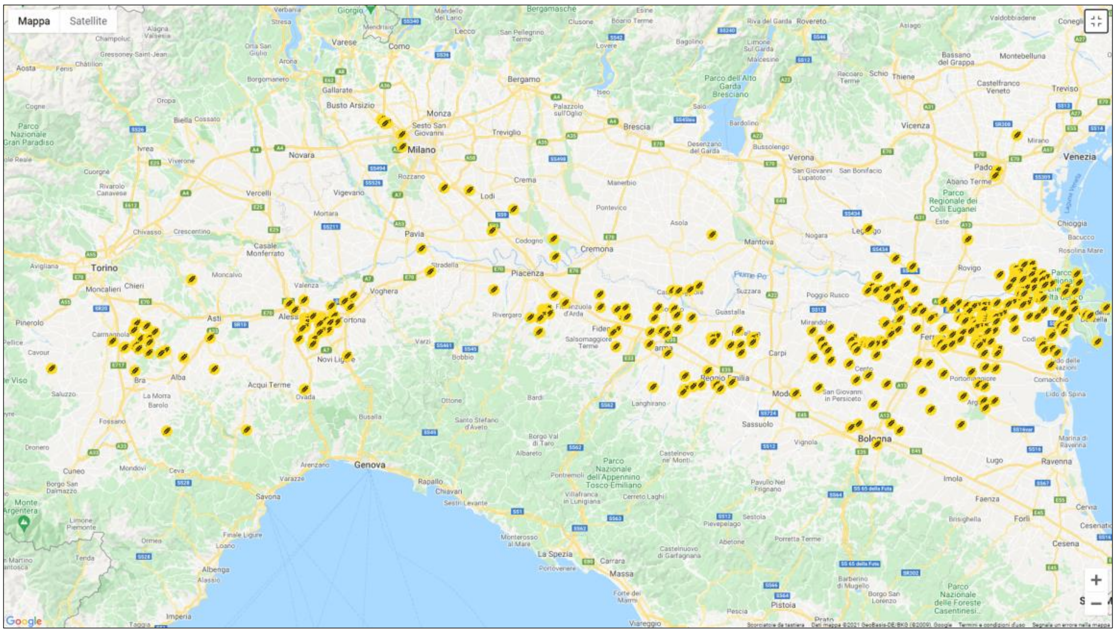


Figure 6 - Farms involve in Carta del Mulino 2020. (Source: https://www.mulinobianco.it/lacartadelmulino)

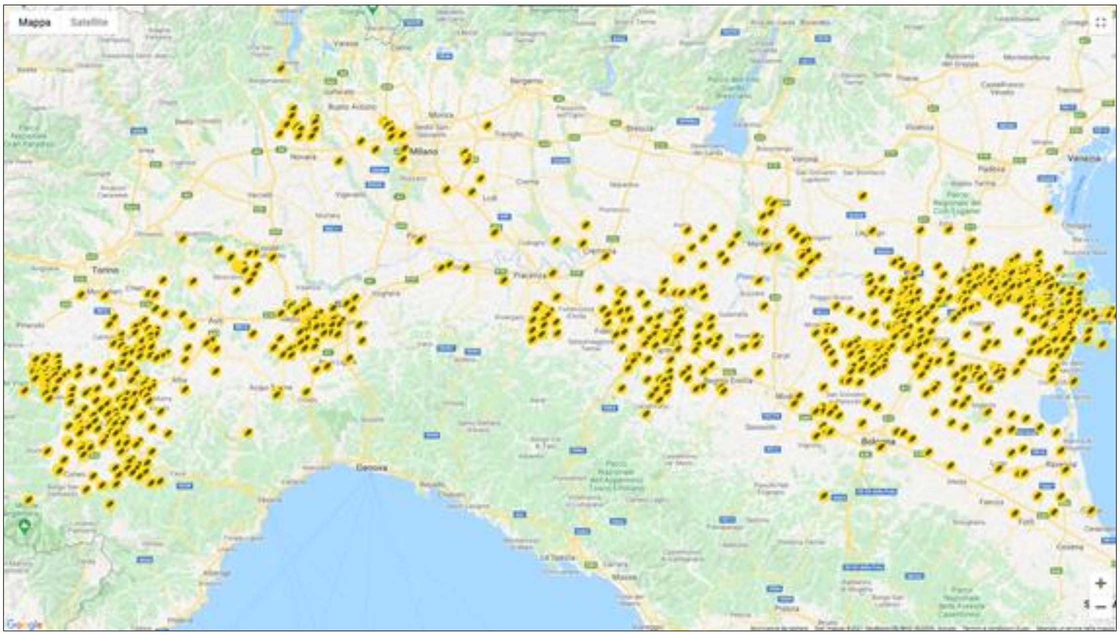
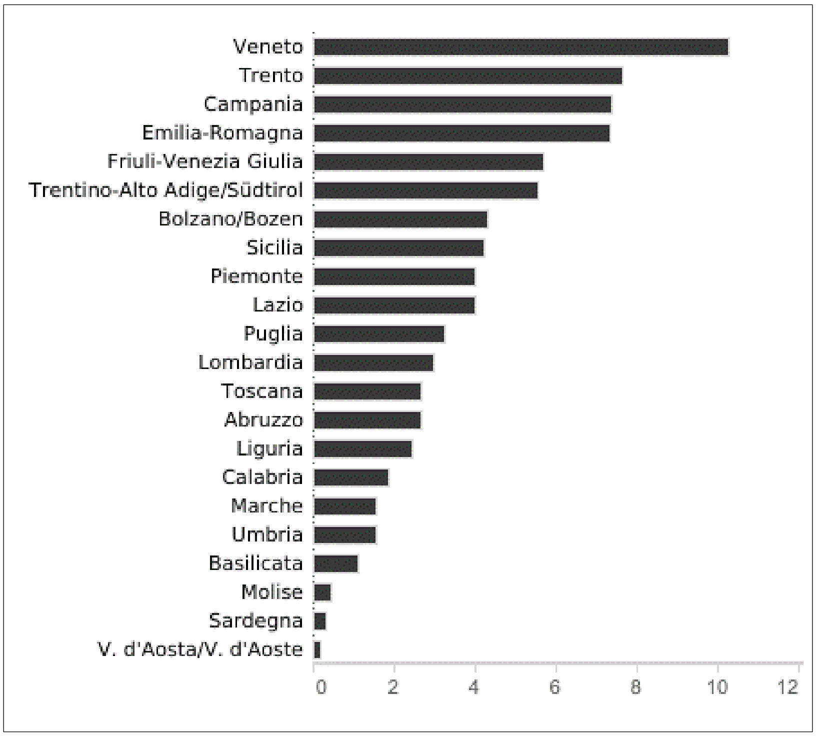


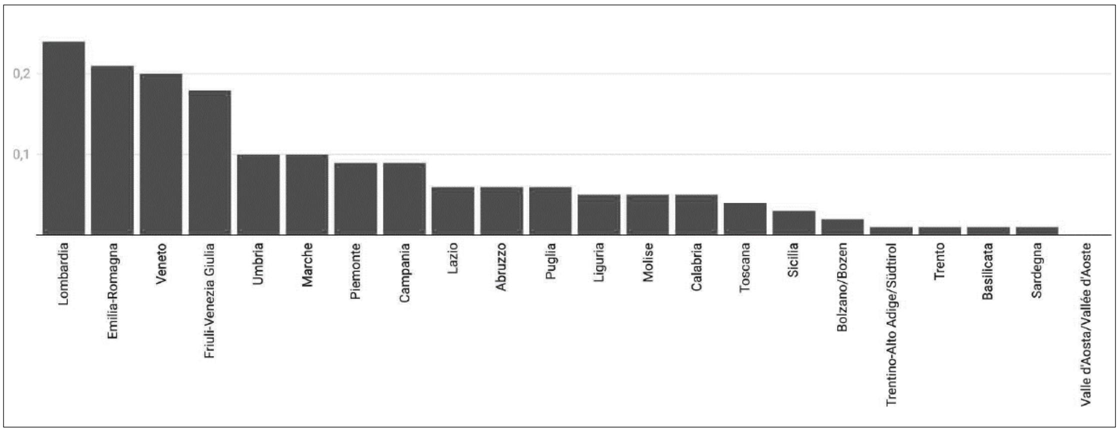
Figure 7 - Farms involve in Carta del Mulino 2021. (Source: https://www.mulinobianco.it/lacartadelmulino)

The Po Valley is characterized by intensive agriculture whit agricultural areas above the Italian average, an important use of fertilizers and pesticides, high levels of mechanization. From Istat[4] data we can observe that in 2016, the average size of Italian farms (11.0 hectares), in terms of surface, shows significant differences at the territorial level. The average size is largest in the North-West (19.7 hectares) and smaller in the South (8.8 hectares). Again, according to ISTAT, 114.4 million kilograms of plant protection products were distributed in Italy in 2019, of which 54.9% in the North. In particular, the North-East is the geographical area with the highest quantity of active ingredients contained in plant protection products distributed per hectare of UAA (equal to 7.88 kilograms per hectare of UAA – graph 3) and the area with the greater distribution of overall fertilizers (36.7% of the total Italy). In 2019, the quantity of simple fertilizers distributed per hectare of UAA is higher in the North-East with 0.18 tons (Graph 4).



Graph 3 - Active ingredients. Year 2019 (Kg per hectare of UAA). Source: Istat - survey on the distribution of plant protection products for agricultural use

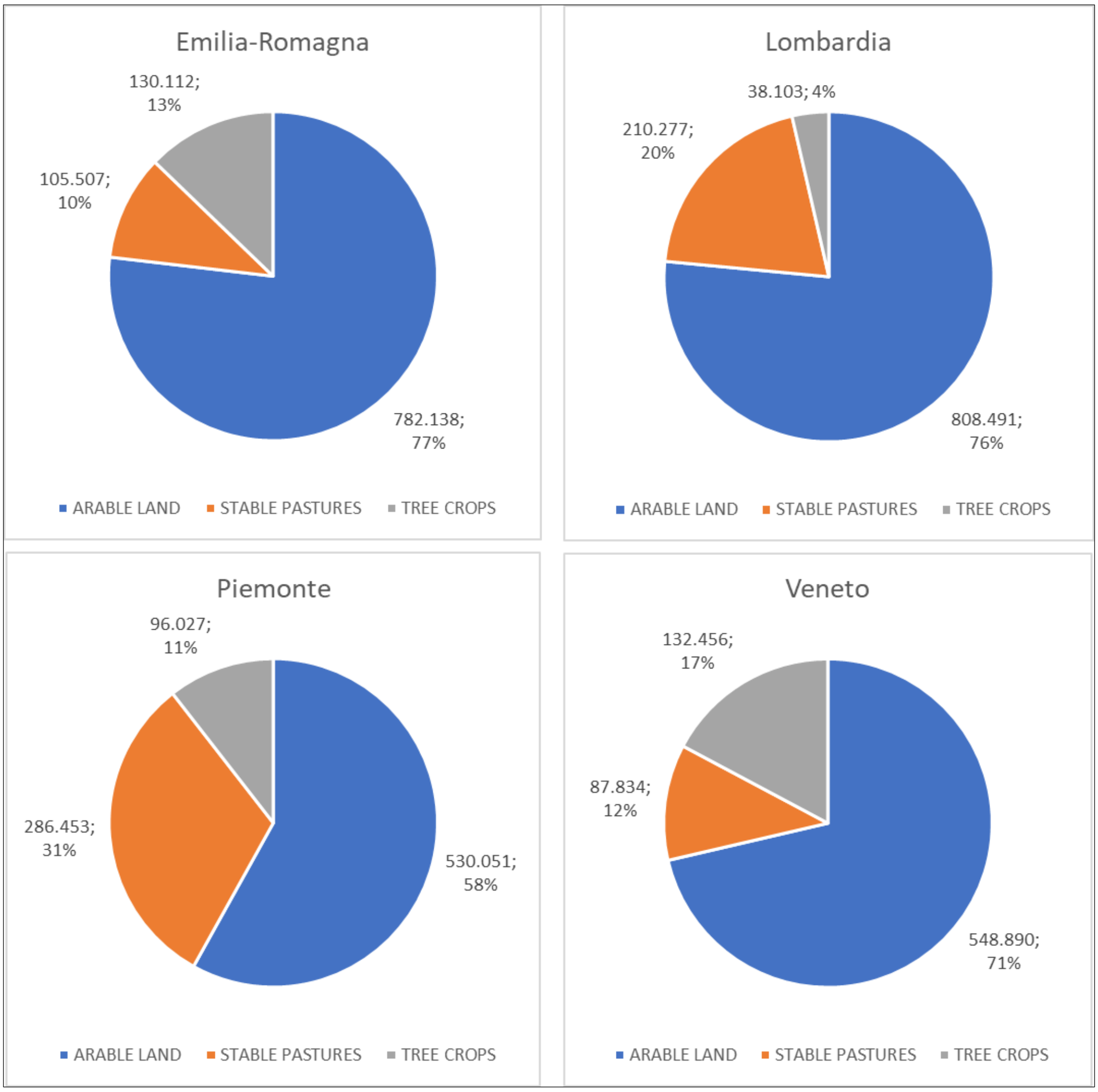
[4] processing and interpretation of the data on the page https://noi-italia.istat.it/pagina.php?id=3&categoria=11&action=show#. Section Dashboard – Agriculture.



Graph 4 - Simple fertilizers. Year 2019 (Tons per hectare of UAA). Source: Istat, Survey on the distribution of fertilizers for agricultural use

In support of this data snapshot, before proceeding with the processing of specific data for farms adhering to the "Carta del Mulino" specification, it was decided to create an information database that would provide a scenario on the current situation of the regions concerned, to be able to contextualise the sampled farms in the best possible way. Using Istat data as a source, the database created covers a time span from 2016 to 2020 and contains the values of UAA occupied by the most represented crops in the four target regions of the case study (Emilia Romagna, Veneto, Piemonte e Lombardia).

If we look at the total UAA of those regions we can see their high specialization in arable land productions. The following graphs shows the 5 years mean value (2016-2020) of UAA divided in three macro categories: arable land; stable pastures; tree crops (Graph 5). In Emilia Romagna and Lombardia we found the higher arable land surface whit more than 780.000 ha. It follows Veneto and Piemonte with more than 530.000 ha. As we can see all the regions have more than 70 % of their UAA dedicated to arable land. Only in Piemonte we found the 58% dedicated to arable land, because the 31% are involved in stable pastures, especially in mountain areas. Emilia-Romagna and Veneto have more than 130.000 ha involved in tree crops: fruits and vineyard for the first and vineyard for the second one.

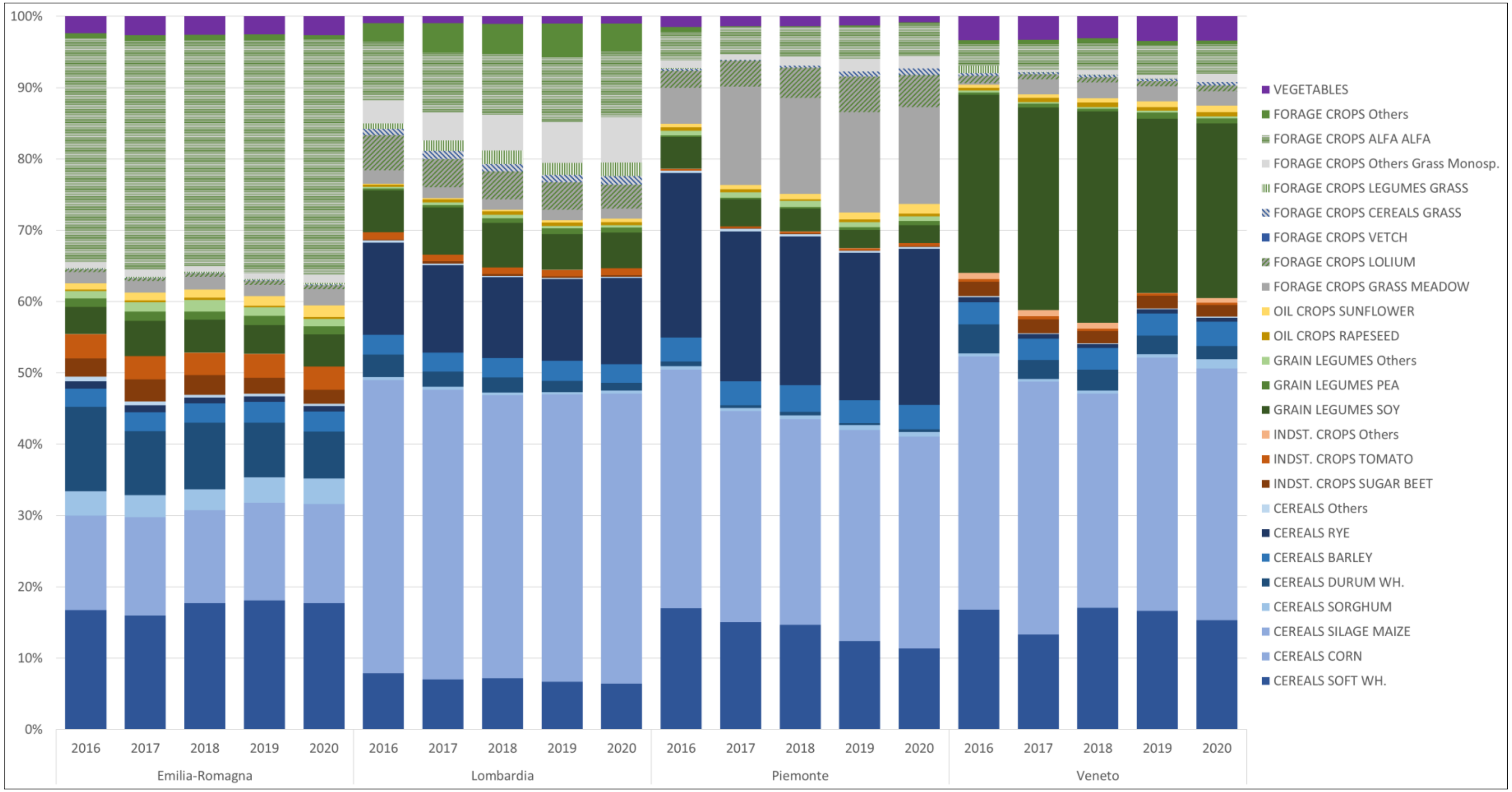


Graph 5 – Region's UAA in hectares (ha). Five years mean value: 2016-2020. Source: own elaboration on Istat data base (http://dati.istat.it)

The following tables show the details of the land use of arable crops for each region over a period from 2016 to 2020. These detailed data are of particular importance for the interpretation of the evolution of arable lands within the target regions. The table shows the main crops grown within the regions. Crops are grouped into categories dictated by their botanical and cultural characteristics and their product characteristics (Table 7). The graph on the next page shows the same UAA data for the destination region (Graph 6) in percentage terms.

Table 7 - Total area (Ha) of the main crops of the target regions of the case study.

CATEGORIES	CROP	Emilia-Romagna					Lombardia					Piemonte					Veneto				
		2016	**2017**	**2018**	**2019**	**2020**	**2016**	**2017**	**2018**	**2019**	**2020**	**2016**	**2017**	**2018**	**2019**	**2020**	**2016**	**2017**	**2018**	**2019**	**2020**
CEREALS	SOFT WH.	130.669	122.602	137.000	143.144	140.971	62.027	56.556	58.761	54.767	51.868	85.805	82.156	77.580	66.973	60.043	90.195	72.642	95.018	91.189	85.120
	CORN	65.719	66.001	57.170	62.425	62.144	147.016	145.567	138.642	140.665	136.625	148.855	143.366	134.812	138.891	137.422	169.709	165.352	136.955	161.475	153.691
	SILAGE MAIZE	37.677	39.812	43.516	45.735	48.902	176.071	182.615	186.125	189.995	192.525	19.864	18.564	18.125	20.752	19.798	21.453	27.485	29.966	33.392	42.731
	SORGHUM	26.966	23.800	22.712	28.289	28.361	3.288	3.489	2.752	2.921	3.687	2.597	2.288	2.679	3.821	3.514	2.415	2.146	2.662	2.883	7.256
	DURUM WH.	92.303	68.699	72.124	60.774	52.306	24.760	17.121	17.459	12.937	8.936	3.170	2.136	2.613	1.522	2.022	21.873	14.655	16.169	14.069	10.176
	BARLEY	19.999	20.616	21.287	23.133	22.874	21.992	21.346	22.448	23.034	21.051	17.109	18.462	19.730	17.185	18.285	16.689	16.187	16.857	17.240	19.044
	RYE	8.076	7.530	6.325	6.123	5.964	101.691	99.159	92.862	94.218	97.861	116.325	114.950	110.520	111.632	115.724	3.616	3.383	3.248	3.242	3.172
	Others	4.970	4.178	2.642	2.916	2.750	2.327	1.771	1.096	1.241	1.461	1.746	1.887	1.790	1.453	1.547	910	694	512	577	837
INDST. CROPS	SUGAR BEET	19.899	23.735	21.503	17.613	15.332	1.024	2.672	2.323	1.603	1.412	..	573	620	303	444	11.058	10.723	9.697	9.883	9.084
	TOMATO	26.456	24.834	24.125	26.461	25.833	7.971	7.510	7.263	7.406	7.923	1.202	1.175	1.137	1.440	2.325	2.007	2.390	1.741	1.668	1.713
	Others	149	90	121	156	107	39	95	150	126	122	133	134	217	138	90	4.553	4.673	4.427	335	3.776
GRAIN LEGUMES	SOY	29.655	38.062	35.738	31.918	35.886	46.091	53.344	51.001	41.310	40.708	22.601	20.824	16.938	14.051	13.088	134.275	154.676	165.261	133.943	136.075
	PEA	9.523	9.663	9.141	10.105	9.173	2.301	2.763	5.625	6.621	5.660	1.151	1.148	1.303	2.005	3.178	1.848	2.791	2.056	4.933	3.866
	Others	8.200	10.176	12.516	9.622	8.392	1.488	2.892	3.894	2.683	2.398	3.165	4.188	4.595	3.687	3.390	1.401	1.380	1.283	1.423	1.577
OIL CROPS	RAPESEED	1.602	2.048	2.365	1.890	2.091	2.370	3.756	3.831	3.850	3.404	2.471	2.301	1.085	2.016	2.260	2.037	3.128	3.366	2.800	3.216
	SUNFLOWER	6.567	8.530	8.944	10.700	13.063	1.237	1.417	1.987	2.592	3.984	2.604	3.358	4.003	5.441	7.185	2.488	2.746	3.341	4.397	5.360
FORAGE CROPS	GRASS MEADOW	12.583	12.227	13.665	12.329	17.854	14.783	12.113	11.785	12.115	11.685	25.242	75.228	71.229	75.752	71.730	1.248	11.414	12.417	11.714	11.105
	LOLIUM	2.914	3.252	3.716	4.709	4.689	38.796	32.159	32.270	31.729	27.332	12.139	19.925	22.502	27.023	23.980	5.558	3.778	3.902	3.609	4.496
	CEREALS GRASS	454	384	822	998	719	6.992	9.020	8.255	8.302	9.315	1.435	622	1.551	3.850	4.742	1.882	1.720	1.924	2.028	2.628
	LEGUMES GRASS	611	908	900	891	1.870	5.960	12.103	15.382	13.847	15.534	375	..	..	..	..	5.588	213	177	124	144
	Others Grass Monosp.	6.257	7.784	5.892	6.804	9.070	25.527	31.731	40.381	47.230	51.907	5.712	4.538	6.110	9.251	9.115	..	1.127	3.455	2.637	6.341
	ALFA ALFA	245.420	246.360	245.190	258.278	262.672	64.908	67.293	70.464	74.715	74.527	20.214	20.682	22.521	24.344	24.282	15.974	20.050	21.833	23.306	22.803
	Others	5.703	6.227	5.909	6.162	5.114	19.796	33.895	34.758	38.542	31.345	3.152	716	622	1.164	817	3.218	3.311	3.282	3.055	3.203
VEGETABLES	-	18.617	20.179	20.198	20.182	20.987	7.734	7.556	8.523	8.317	8.248	7.676	7.537	7.316	6.954	4.526	18.079	17.947	17.082	18.938	18.858
	TOTAL	*780.989*	*767.697*	*773.521*	*791.357*	*797.124*	*786.189*	*807.943*	*818.037*	*820.766*	*809.518*	*504.743*	*546.758*	*529.598*	*539.648*	*529.507*	*538.074*	*544.611*	*556.631*	*548.860*	*556.272*



Graph 6 - Utilized agricultural area in % for the regions involved in the case study. Evolution from 2016 to 2020. Source: own elaboration on Istat data base (http://dati.istat.it)

The data reported in the table and by the graph give us important basic information to understand the area to be analyzed and the related farms case study. All the regions have a high specialization in cereal cultivation.

In Emilia Romagna about 50% of the UAA is dedicated to cereals. Common wheat had a slight increase in the 5 years analyzed, going from about 130.000 ha to over 140.000 ha. The area dedicated to alfalfa (about 30%) is of considerable importance for the same region. The same is steadily increasing slightly over the 5 years, passing from approximately 245.000 ha to approximately 262.000 ha. This extension is justified by the conspicuous presence of farms to produce Parmigiano Reggiano. It is important to note the constant presence of about 10% of industrial crops through the years (tomatoes and sugar beets). Also, in this case their presence is linked to the presence of agro-industries. Lombardia is highly specialized in the production of cereals. The dedicated UAA is over 65% for all the years analyzed. The most represented crop is corn which exceeds 300.000 ha in all 5 years taken into consideration. The second most important cereal is rice with an average value of over 96.000 ha in 5 years. The most present grain legume is soya with a surface area of 45.000 ha in 5 years, corresponding to approximately 5% of the UAA. The most cultivated forage crop is the alfalfa with an average value of 10% of UAA in the 5 years. Also, in Piemonte we find a high presence of cereals throughout the time analyzed. About 68% of the UAA in five years is dedicated to the cultivation of cereals. The presence of corn and rice is very important: more than 150.000 ha every year are dedicated to corn cultivation and more than 110.000 ha of rice. The high presence of rice is justified by the production specialization for the Vercelli province. More than 20% of the UAA in 5 years is dedicated to forage crops. This extension is linked to the presence of livestock. In addition to being characterized by a high presence of cereals (more than 55% and more than 300,000 ha of for each year analyzed), the Veneto region also has a high presence of grain legumes. On average, in the 5 years analyzed, more than 140,000 ha were dedicated to the cultivation of soybeans, equal to 27% of the UAA in the 5 years.

In conclusion, the context in which the case study is analyzed is characterized by the high presence of arable land specialized in the production of cereals. I legumi da granella sono presenti in tutte le regioni ma in proporzioni diverse. The presence of legumes is often linked to the presence of farms for the cultivation of forages crop.

Grain legumes are present in all regions but in different proportions. Industrial crops are linked to the presence of agro-processing industries in the area. Starting from this framework, the cases of specific farms are examined in depth in the next chapter.

CHAPTER 3
MATHERIALS AND METHODS

In this chapter we show the materials and methods used to define the economic impacts of public policies and private initiatives (Carta del Mulino case study) and how those can “pull”, or “push” the case study’s farms to diversify their cropping systems.

From the pool of farms involved in the case study in Italy, some farms were selected in which on field economic data collection was carried out. After, the data were processed and systematized to create a database of useful data for subsequent processing. So, the data has been processed whit a new experimental tool that considering 5 years of future farm’s utilized agricultural area (UAA) in three different production scenarios. The new experimental tool used was specially designed for this work. The research work concerned the design and implementation of the model according to variables specifically defined for the case study considered.

3.1 Identification of the panel of farms

The results obtained from a first year of piloting made it possible to identify a stable panel of farms involved in the case study’s private initiative (CdM). In those farms the goal was to carry out economic surveys for reconstruct the real gross margin range obtained by the cultivation of the arable land crops involved in the case study. Starting from the Istat database, have been identified the provinces with the grater arable land involved in soft wheat for the year 2018 (1st year of CdM) in the target regions for the case study: Emilia Romagna, Lombardia, Piemonte, Veneto.

Those soft wheat surface it was compared with the total arable land involved in crop rotation for every province. From the classification obtained, 30 farms were selected in the most significant provinces for:

- Total arable land dedicated to soft wheat cultivation
- % Soft wheat on Arable land use with crop rotation

However, the COVID-19 lockdown allowed to have data collection for 23 farms instead the 30 planned for 2020 and only 11 farms for the 2021 data collection.. The following table (Table 8) shows the number of farms that will be extracted randomly from the Barilla’s CdM suppliers database that account totally 330 farms in Italy compared to the number of farms where data was collected.

Table 8 - Selection of farms involved in the economic survey.

Region	**Province**	**Arable land use with crop rotation (ha)**	**Soft wheat (ha)**	**% Soft wheat on Arable land use with crop rotation**	**Number of farms in CdM Dtb**	**Planned farms selected for the Survey**	**2020 Number of farms where data was collected**	**2021 Number of farms where data was collected**
Pie	Alessandria	100.018	31.943	32%	27	4	4	
ER	Ferrara	159.468	31.025	19%	73	4	4	3
ER	Bologna	134.506	24.440	18%	9	3	3	2
Ven	Rovigo	115.359	23.362	20%	37	2	2	
Ven	Padova	106.368	21.887	21%		**		
ER	Modena	52.477	19.685	38%	5	2	No audit	
Lom	Mantova	156.287	18.641	12%	14	3	3	
Ven	Venezia	115.904	18.339	16%	1	1	1	
Pie	Torino	106.323	17.466	16%	16	1	1	1
ER	Piacenza	84.046	15.550	19%	25	2	No audit	
Pie	Cuneo	126.169	15.381	12%	56	2	2	2
Ven	Verona	86.418	15.166	18%		**		
ER	Parma	92.225	11.700	13%	5	1	1	1
Lom	Pavia	84.974	11.000	13%	7	1	No audit	
ER	Ravenna	66.948	10.800	16%		**		
ER	Reggio Emilia	75.062	10.500	14%		**		
ER	Forlì-Cesena	41.694	9.700	23%		**		
Lom	Cremona	127.832	8.990	7%	3	2	No audit	
Pie	Asti	32.312	8.798	27%		**		
Ven	Vicenza	48.135	8.337	17%		**		
Ven	Treviso	68.557	7.839	11%		**		
Lom	Brescia	115.828	6.000	5%		**		
Lom	Milano	41.860	4.290	10%	20	2	2	2
Lom	Bergamo	38.924	4.120	11%				
ER	Rimini	23.366	3.600	15%				
Lom	Lodi	51.756	3.120	6%				
Pie	Vercelli	22.507	2.276	10%				
Pie	Novara	20.010	1.500	7%				
Lom	Monza e della Br.	6.244	1.230	20%				
Lom	Como	3.967	505	13%				
Lom	Varese	3.834	485	13%				
Lom	Lecco	2.120	378	18%				
Pie	Biella	5.510	206	4%				
Ven	Belluno	3.040	88	3%				
Pie	Verb.-Cusio-Oss.	454	10	2%				

Lom	Sondrio	1.121	2	0%			
				Total	*30*	*23*	*11*

** province that has no CdM farms / farms not available to have survey

Data collection was carried out with direct on-site surveys. To collect data systematically and not incur in evaluation errors, a standardized survey scheme was developed. This, through a logical path based on the reconstruction of the single farm crop itinerary, has possible to identify:

- farm’s Utilized Agricultural Area (UAA)
- arable land use and management for all the crops, flower strips included
- quantity and unit prices of the technical inputs used: pesticides; fertilizers; seeds.
- mechanization costs and techniques
- agricultural contractor’s rates
- products selling price and quantity sold
- premium price received per ton of “Carta del Mulino” wheat
- subsides received (CAP; CMO; RDPs)

All the data collected was collected through direct interviews with farmers, technicians and by viewing documents such as invoices, contracts, or others.

3.2 Collection and systematization of technical and economic data

Inputs, yields and agricultural management practices related data collected at farm level are elaborated using a semi-automatic excel file, called DIFARMA_CDM.

DIFARMA_CDM tool was created and used to allow data collection useful to obtain variables necessary to assess Gross Margin values per crops/plot/farm per years. In the case study considered, the plot coincides with the crop practiced. With a total of 7 sheets integrated and consequential to each other, DIFARMA allows to collect and elaborate data about all kind of explicit costs and revenues and, also, to manage different data input for different crop management (i.e. Standard Soft wheat vs CdM Soft Wheat). For each farm, the data imputation is sequential, starting from sheet “Plot Archive” up to the results that are viewable in sheet “Resume”. The 7 sheets are as follows:

1. Plot Archive: single plots and subplots of the case study are defined by basic information on crops, UAA surface and transplanting or seeding density.
2. Seeds Pesticides Fertilizer: it is the archive of all input available (fertilizers, pesticides, seed/plants) in the farm warehouse. Per each input typology are described quantities and prices using value gathered directly by invoices.
3. Cultivation Operations costs: this sheet can identify the cultivation operations costs starting from the agricultural contractor's rates for the specific farm area. So, the costs related to mechanization and labour to be attributed to the single crop were determined through an estimation process. In particular, for this research purposes, define the costs on the real machinery pool and the number of hours spent in labours can be not representative, because every single farmer has a different machine in terms of years and power, and different organization in labour. The aim of this process is to identify a cultivation cost that takes into consideration fixed costs (depreciation rates; machine insurances) and variable costs (fuel; oils; maintenance fee; work hours). For doing this, it was considerate appropriate to discount contractor's rates detected during the surveys. These rates are defined as the contractor's net profit (15-20%) that are assessed by province and type of operation.
4. Diary: It is a logbook, where all the operation carried out on the single plot or subplot are reported by date. Several columns of these sheets are connected with the previously filled sheets. Thus, making available all the information previously collected.
5. Subsides: Archive of all kind of subsides received by farmers and allocated per single plot, make different attribution considering the subsidy typology (Direct Payment decoupled - CAP) or coupled (Common Market Organization - CMO); Agro-environmental-climate schemes (RDP). In this sheet are collected also the eventually insurance contribution received per each crop.

6. Revenue: Automatic collection of values relating to the observed quantities of product and the revealed price per unit, indeed are calculated gross sales value of single plot.
7. Resume: Collection in the table of the revenues, variable costs, labour costs, external services, insurance differentiated for each single plot. By choosing the plot of interest it is possible to read the previous detailed data.

To improve data gathering accuracy, some GM key variables are imputed in DIFARMA_CDM following a double check and pre-assessment process. Instead, costs that are not reported in accounting documents and not measured on field, are derived through estimation process based on farm information collected by deep farmers interviews and adjusted with official data published in technical documents. These data are, own labor costs, fixed costs. Finally, to operate comparisons between performance carry out from cropping systems driven by multi-years contract, special attention was dedicated to collected data of subsides and premium price and to define a baseline costs reference.

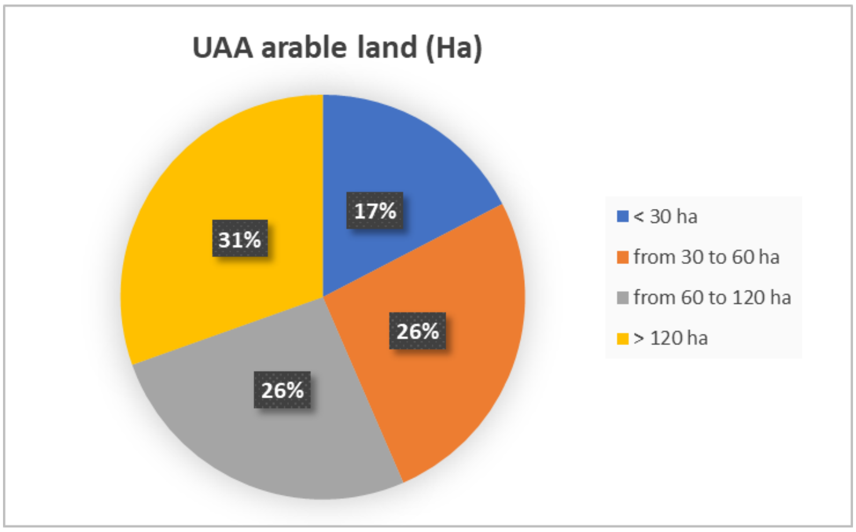
3.3 Panel: farm's structure

The data collection allowed to identify the main structure of the farms involved in surveys. The results of a sample's first analysis show specialized and competitive farms.

Below is a general picture that summarizes for each farm sampled the Agricultural Area used for arable land, the hectares of surface cultivated with soft wheat, the hectares of surface occupied by the flower strip (Table 9). Based on this information, it is possible to define in more detail the structure and use of arable land of the sampled companies that adhere to the "Carta del Mulino". By taking the size parameter as a reference, it was possible to classify farms into four categories based on the UAA for arable land (Graph 7): farms with arable land UAA of less than 30 ha; farms with arable land UAA between 30 and 60 ha; farms with arable land UAA between 60 and 120 ha; farms with arable land UAA exceeding 120 hectares.

Table 9 - Main farm's characteristics

Farm Cod.	*Region*	*Province*	*UAA arable land (Ha)*	*Cdm Soft Wheat (Ha)*	*Cdm Flower strips (Ha)*
BO1	Emilia Romagna	BO	161	38,8	1,2
BO2	Emilia Romagna	BO	229	88,27	2,73
BO3	Emilia Romagna	BO	72	44,62	1,38
FE1	Emilia Romagna	FE	177	50,44	1,56
FE2	Emilia Romagna	FE	89	11,64	0,36
FE3	Emilia Romagna	FE	23	8,73	0,27
FE4	Emilia Romagna	FE	27	4,85	0,15
PR1	Emilia Romagna	PR	29	8,73	0,27
MI1	Lombardia	MI	53	22,08	0,92
MI2	Lombardia	MI	51	29,45	1,55
MN1	Lombardia	MN	86	15,52	0,48
MN2	Lombardia	MN	66	6,79	0,21
MN3	Lombardia	MN	84	8,73	0,27
AL1	Piemonte	AL	154	6,79	0,21
AL2	Piemonte	AL	120	20,16	0,84
AL3	Piemonte	AL	54	6,79	0,21
AL4	Piemonte	AL	84	49,425	1,575
CN1	Piemonte	CN	62	24,25	0,75
CN2	Piemonte	CN	33	4,85	0,15
TO1	Piemonte	TO	19	12,61	0,39
RO1	Veneto	RO	49	18,43	0,57
RO2	Veneto	RO	134	4,85	0,15
VE1	Veneto	VE	211	22,31	0,69



Graph 7 - Classification of farms based on UAA dedicated to arable crops

In terms of arable land, the 82% are bigger than 30 ha, specialized in field crops. Only four farms have livestock process. All the farmers are professional entrepreneurs and the 40% are involved in Agro-environmental-climate schemes (RDP), mainly integrated pest management. The 40% of the farms are in the third year of the "Carta del

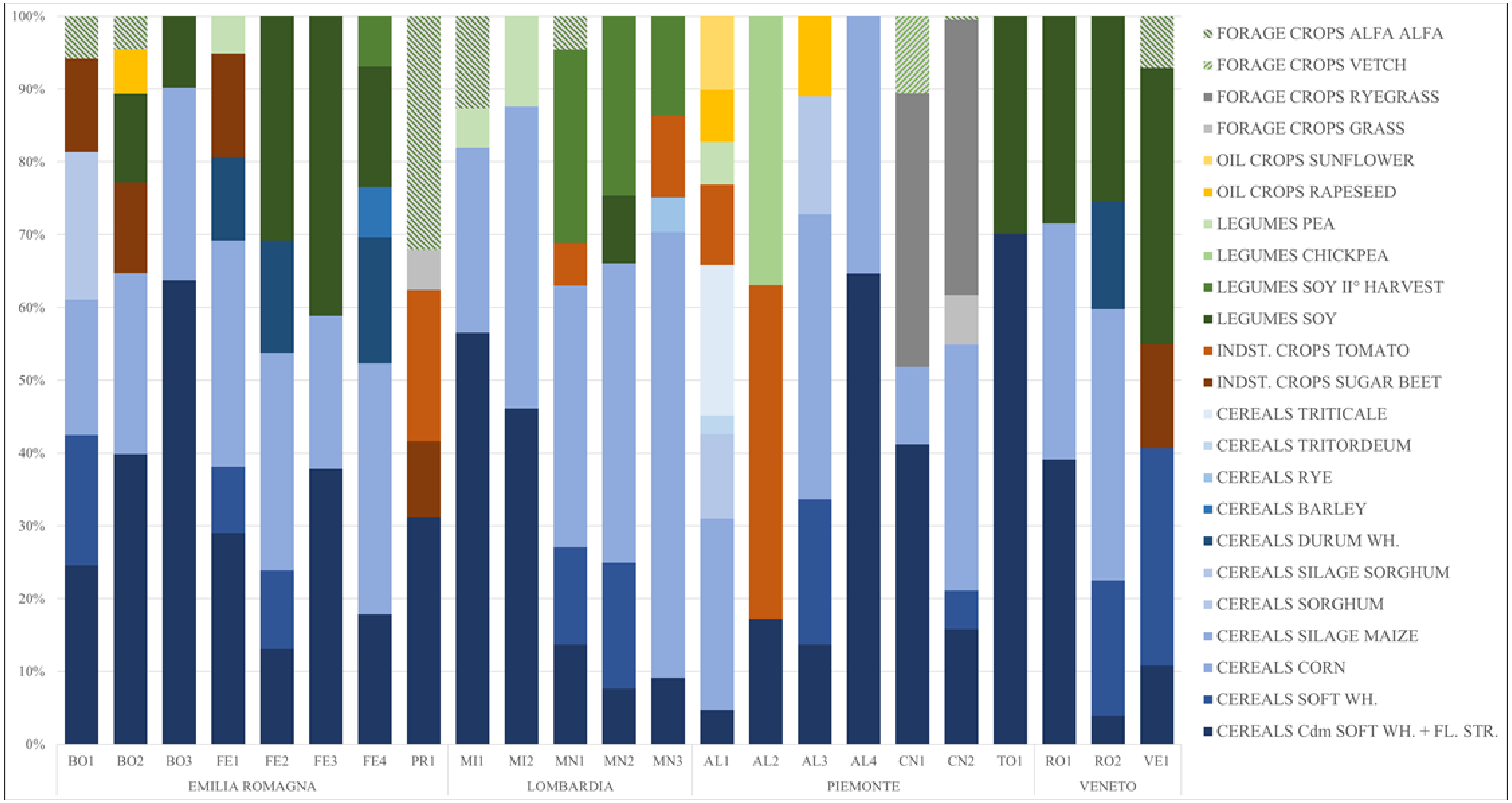
Mulino" Certification scheme. The analysis of the farm's utilized agricultural area (UAA) shows differences in terms of production specialization of the arable land. These are attributable to different cultivation areas and different standard cultivation techniques adopted.

The graph reported in the following page shows the utilized agricultural area for the farms involved in the survey divided per region (Graph 7). The crops are chromatically divided in five main groups according to crop rotation needs: cereals; industrial crops; legumes; oil crops; forage crops.

The graph shows a great difference in crop diversification between the farms: from a minimum of 2 crops to a maximum of 9. All the farms are specialized in cereals production (wheat and corn). In fact, the medium value of cereal's UAA is 68%.

The area dedicated to soft wheat involved in CdM is variable: from 4% minimum to 70% maximum. It is important note that these areas represent the CdM contract object in the further agrarian years. Nine farms grow industrial crops in about 20% of their UAA. These farms are in provinces where there is a great technical specialization on industrial crops consolidated in the years, thanks to the presence of related agroindustry. The forage crops production is in the provinces where animal productions still relevant for agro-industry (Ham; cheese; milk; Parmiggiano Reggiano): Bologna; Parma; Mantova; Cuneo. The forages crops UAA is the 20% in 8 farms. Only 3 farms are involved in oil crops production withs small area dedicated (11% of UAA). Seventeen farms are involved in legumes production with a UAA medium value of 22%. The major crop utilized is soybean in all the region.

So, the farms involved in survey are specialized in cereals production and all of them have a legumes crop or an oil crop. However, the distribution of crop areas within farms is not uniform. Cereal have a UAA more than 60 % in all farms and legumes/oil crops are on 20%. This will be a constrain to follow the second CdM's rule (five years crop rotation with three different crops as minimum one of those crops must be a nitrogen fixers crop or an oil crop) where the UAA invested in this initiative exceeds 25% of total arable land. Those data confirm the values at region level analysed in the previous chapter. So, we can say that are representative for the regions.



Graph 8 - Utilized agricultural area in % for the farms involved in the survey.

3.4 Data elaboration tool

A collaboration whit the Siena University “Dipartimento di Ingegneria dell' Informazione e Scienze Matematiche”, have made possible to create an experimental decision support tool that can help farm management in terms of crop rotation planning for the annual crops.

The bibliography offers different example of crop rotation planning tools already used. Haneveld (2004) proposed to write crop succession requirements as linear constraints in an LP-based model for agricultural production planning. Crop succession information is given in the form of a set of inadmissible successions of crops. The decision variables represent the areas where a certain admissible sequence of crops is cultivated (Haneveld and Stegeman, 2005). Detlefsen (2007) consider the problem of finding an optimal crop rotation for a given selection of crops on a given piece of land. He shown techniques from network modelling can be used to model this problem, which has the advantage that special algorithms for solving network problems can be developed and applied to solve the crop rotation problem (Detlefsen and Jensen, 2007). Dury (2011) proposed a review of more more than 120 references where cropping plan and crop rotation decision concepts were incorporated into models. He found that cropping plan decisions selection and design have been done using many approaches based on different objectives and handled at very different scales (Dury *et al.*, 2012). Bachinger and Zander (2006) presents ROTOR: a static rule-based model based on a set of annual crop production activities assembled semi-automatically from single site and crop-specific field operations using a relational database working on all possible sequences of 3-8 year of crop rotation (Bachinger and Zander, 2007). Li et al. (2015) proposes an operational model that considers a crop rotation scheduling for an investor that offers contracts to many smallholder farmers (Li *et al.*, 2015). A heuristic algorithm was designed to identify the optimal rotation scheduling that would achieve both objectives of maximizing prices and minimizing the profit differences between smallholder farmers. Capitanescu et al. (2017) presents a novel multi-stage optimization model for farm management during a certain planning time horizon. The decision support tool proposed produces an optimal crop rotation plan which maximizes farmer' profit while satisfying specified environmental constraints and crop rotation schemes requirements (Capitanescu *et al.*, 2017). Cortigiani and Dono (2020) in a recent paper proposes an assessment of the possible effects of the crop diversification proposed by CAP the arable crops sector in Italy. For doing this they use a mathematical programming model calibrated and validated by way positive approach and isconducted on data of about 2800 Italian farms of the Farm Accountancy Data Network (Cortignani and Dono, 2020). Therefore, from the bibliographic review it emerges that the model must be very flexible and "taylor-made" on various constraints. A more representative database is the key to the work to achieve meaningful results. For this we propose a specific model that can help us to answer at the research question proposed.

The tool created for this research in collaboration whit the Siena University[5], is a Mixed Integer Linear Programming model in which all the operational and crop rotation schemes constraints have been included. For each hectare of the farmland, the model is able to take into account both the rotation requirements and the specific constraints for each crop, considering all suitable combinations of crop sequences. The objective is the maximization of the gross income coming from the cultivation of all the farm's UAA for a given period. This data elaboration it is based on maximizing the gross income deriving from the cultivation of each hectare: for the specific crop; for the considered period. So, in this section an Integer Linear Programming formulation is presented for CRP-k.

The objective is to maximize the total profit following the formula:

$$\max \sum_{t\in T}\sum_{c\in C}\sum_{r\in R} P_c n_{c,r}^t - \sum_{t\in T}\sum_{c\in C}\sum_{r\in R} I_r C_c n_{c,r}^t \qquad [3.1]$$

where *Pc* is the profit attained by cultivating crop *c*, *Ir* is the percentage increase in cultivation costs *Cc* when the rotation scheme *r* occurs (Cf. 1.3.3), and $n_{c,r}^t$ is the number of hectares assigned to crop *c* in period *t* following the rotation scheme *r*. The decision variables and the details about the complete formula used are not fully reported because are in the patent phase.

[5] Prof. Paolo Detti, PhD student Mario Benini.

The model can solve the objective formula whit different constrains related to the crop rotation that can be divided in two groups: agronomic constraints related to the cultivation of arable land; scenario constrains related to the different production scenario tested. The following pages show the two types of constraints placed in the model and how they were set up.

3.4.1 Agronomic crop rotation constrains

The agronomic constraints deriving from crop rotation over the years of the different crops were considered within the tool. To make a reasoned approach possible and give the "right weight" to the possible crop rotation carried out by farms, additional costs have been defined based on considerations regarding the scientific literature reviews.

The definition of the best crop rotation practice is based on classical agronomy literature (Giardini, 2002) recognized as virtuous agronomic practices following Organic agriculture principles. In Italy, organic agriculture defines proper crop rotation schemes by ministerial decree "DM rotazioni 18 luglio 2018, n. 6793 modificato da DM 9 aprile 2020 n 3775". Indeed, it is reported that the same crop species came back on the same UAA after 2 cycle of different crops species. One of those must be a nitrogen fixers crop. Considering all, the best crop rotation is connected to the rotation of 3 crops in the following chronological sequence:

1. Renewal crop: spring/summer crops
2. Impoverishing crop: winter cereals
3. Improver crop: legumes/nitrogen fixers crops

The benefit coming from the improvers crops in a crop rotation are based on a scientific literature review focused on irrigated systems in central Europe and north Italy. The review started from scopus, by the key words search crop rotation; ecosystem services; crop diversification; nitrogen fixers crops. In much of the literature analysed, reference is made to two types of crop rotations: short-term rotations and long-term rotations. The first one considering a 3-year crop rotation (ex: corn-soy). The second taking in account crop rotation with pastures, sorghum, alfalfa, pea, clover. The following tab show the review of the most important crop rotation's benefits in terms of environmental benefits.

Table 10 - Crop rotation case studies review.

Benefits	Short period crop rotation	Long period crop rotation	References
Nitrogen supply	The nitrogen from the soy-corn rotation is less or negative	greater nitrogen supply especially with organic fertilization	(Bullock, 1992) (Karlen *et al.*, 1994)
Organic matter	reduction of organic matter because soy does not produce enough biomass	higher content in the presence of poly-annual legumes crops (alfalfa)	(Bullock, 1992) (Karlen *et al.*, 1994) (Berzsenyi, Gyorffy and Lap, 2000)
Carbon intake	low contribution of total organic carbon	higher content in the presence of poly-annual legumes crops (alfalfa)	(Bullock, 1992) (Karlen *et al.*, 1994)
Soil structure	Biomass reduction leads a decrease of soil structure	Improvement of soil structure stabilization	(Lieberman and Dick, 1993)
Pest and weeds control	Low control on some weeds and pests	Low control on some weeds and pests	*Lupwayi et al., 1993*
Microbial diversity	Biomass reduction leads a decrease of microbiological presence.	Increase of microbial activity by the inclusion of grass and pastures	*Lupwayi et al., 1993* (Venter, Jacobs and Hawkins, 2016)
Yields	Good yields of soy in rotation with corn or sorghum	Better yields than monoculture	(Bullock, 1992) (Karlen *et al.*, 1994)

Cultivation schemes based on monoculture compared to schemes based on crop rotation allow to identify the limits of a rotation not based on the best agronomic scheme. To identify these limits, a bibliographic review was carried out as shown in the following table (Table 10).

Table 11 - Bibliographic review: effects of monoculture vs crop rotation.

Topic - Title	Main Results	Reference
Continuous Tomato Monoculture experiment	Decrease of soil enzyme activities, soil microbial abundances, soil chemical properties, soil SMC functional diversity, and yield	(Fu et al., 2017)
Long-term effects of crop succession, soil tillage and climate on wheat yield and soil properties	In a context of conservation agriculture promotion, long-term field experiment provides key evidence that the combination of both minimum soil tillage and crop rotation improves soil fertility and crop productivity.	(Sanginés de Cárcer et al., 2019)
Resource use at the cropping system level	The use of special crops to prevent the need of high inputs of crop protectants or to reduce losses of nutrients at the level of the cropping system deserves special attention in research. Examples are given for the ecological control of soil-borne fungi, parasitic weeds, nitrogen loss and other sustainable techniques to increase the resources efficiency at the cropping system level.	(Struik and Bonciarelli, 1997)

Long-term continuously monocropped changed the abundance and composition of soil bacterial communities	Decrease in diversity and abundance of bacterial communities, especially beneficial communities, and simplification of bacterial community function with long-term peanut monocropping could be the main cause of peanut soil sickness	(Chen et al., 2020)
Effect of Crop Rotation and Cereal Monoculture on the Yield and Quality of Winter Wheat Grain and on Crop Infestation with Weeds and Soil Properties	Winter wheat cultivation in the CM system resulted in a decrease of grain yield by 32%, compared to the CR system. The number and air-dry weight of weeds were higher in the CM than in the CR system by 57.1% and 75%, respectively. The soil samples collected from the CM plot contained less organic C and total N than the samples derived from the CR system. Soil samples from the CM system had also a lower number of earthworms compared to the CR soil samples.	(Woźniak, 2019)
The Influence of Long-Term Different Crop Rotations and Monoculture on Weed Prevalence and Weed Seed Content in the Soil	The objective of the study was to compare the effects of different cropping sequencing (#1: continuous v. rotational), on the yield stability of winter wheat; yield risk (the probability of yield falling below a threshold yield level) and inter-annual yield variability were used as stability indicators of the effects. The results showed that rotational cropping combined with sufficient mineral N fertilizer, ensured stable wheat yields while reducing yield risk. In contrast, higher yield risks and inter-annual yield variabilities were found in continuous wheat sections.	(Butkevicien et al., 2021)
Crop rotations sustain cereal yields under a changing climate	Using seven long-term experiments across a wide latitudinal gradient in Europe, we showed that growing multiple crop species in a rotation always provided higher yields for both winter and spring cereals (average +860 and +390 kg ha−1 per year, respectively) compared with a continuous monoculture.	(Marini et al., 2020)
The Impact of Herbicide-Resistant Weeds in a monocropping system	Monocropping systems and repeated use of the same or similar herbicides in some areas of the state of Kansas in the development of herbicide-resistant weeds. This can have an immediate and a long-term effect on the cost, implementation, and effectiveness of weed control programs. The recommended management strategies for herbicide-resistant weed populations include an integrated system of crop rotation.	(Peterson, 1999)
Long-term Effects of Crop Rotation and Different Fertilization Systems on Soil Fertility and Productivity	Effects of crop rotation and fertilization systems on yield and soil fertility parameters have been investigated in a long-term field trial established in southeast Norway in 1953. The results indicate differences between crop rotations and different fertilization systems in yield and soil fertility parameters; the decreasing trend in soil organic carbon and increasing trend of N with time and, as a result, the decreasing trend in C/N ratio.	(Cuvardic et al., 2014)
Effects of agricultural management practices on soil quality: A review of long-term experiments for Europe and China	Effects of four paired agricultural management practices (organic matter (OM) addition versus no organic matter input, no-tillage (NT) versus conventional tillage, crop rotation versus monoculture, and organic agriculture versus conventional agriculture) on five key soil quality indicators. effects were analysed through indicator response ratio (RR) under each paired practice. For this we considered data of 30 long-term experiments collected from 13 case study sites in Europe and China. These were complemented with data from 42 long-term experiments across China and 402 observations of long-term trials published in the literature. The most favourable effect was reported on earthworm numbers, followed by yield, SOM content and soil aggregate stability. Crop rotation had a positive effect on SOM content and yield; rotation with ley very positively influenced earthworms' numbers.	(Bai *et al.*, 2018)
Impact of agricultural management practices on the nutrient supply potential of soil	Soil organic matter (SOM) has the potential to supply substantial quantities of nutrient. The practices comprised conventional (CT) and reduced tillage (RT) with mixed farming, no-till with continuous	(Sarker *et al.*, 2018)

organic matter under long-term farming systems	cropping (NT), and perennial pasture (PP) in the semi-arid Luvisol, while in a Mediterranean direct-drilled continuous cropping system, stubble was either retained (SR) or burnt (SB). The results indicate that SOM is a ready source of plant available P and S (in addition to N), and tillage and stubble retention generally enhanced SOM mineralisation and nutrient release, which varied with soil type.	
Benefits of increasing plant diversity in sustainable agroecosystems	Plant diversity potentially provides a partial to complete substitute for many costly agricultural inputs, such as fertilizers, pesticides, imported pol-linators and irrigation. Diversification strategies include enhancing crop genetic diversity, mixed plant-ings, rotating crops, agroforestry and diversifying landscapes surrounding croplands. Here we briefly review studies considering how increasing plant diversity influences the production of crops, forage, and wood, yield stability, and several regulating and supporting agroecosystem services. The benefits of diversifying agroecosystems are expected to be greatest where the aims are to sustainably intensify production while reducing conventional inputs or to optimize both yields and ecosystem services.	(Isbell *et al.*, 2017)

From this review emerges that crop rotation systems have more benefit compared to the monocropping system. The results coming from those long-term experiments allowed to identify crop diseases carried out by the monocropping practice:

• loss of yield

• loss of soil fertility

• increase of weed and pest diseases

In other words, to keep their yield stable over time, farmers will have to compensate for the loss of soil fertility, the increase in weeds and pests problems with an increase in technical inputs such as herbicide fertilizers and pesticides. The increase in the use of technical inputs leads to an increase in costs weighted based on the crop succession in the rotation scheme.

The following table shows all the crop rotations possible combinations of the three different crop's typologies related to the increase of technical inputs costs (Table 12).

Table 12 - Possible crop rotations and increase of technical inputs costs.

Crop rotation scheme			Increase of technical inputs costs [Ir]	
year 0	year 1	year 2	year 1	year 2
Impoverishing	Impoverishing	Impoverishing	20%	30%
Impoverishing	Impoverishing	Renewal	20%	0%
Impoverishing	Impoverishing	Improver	20%	0%
Impoverishing	Renewal	Impoverishing	0	10%
Impoverishing	Renewal	Renewal	0	10%
Impoverishing	Renewal	Improver	0	0
Impoverishing	Improver	Impoverishing	0	0
Impoverishing	Improver	Renewal	0	0
Impoverishing	Improver	Improver	0	10%
Renewal	Impoverishing	Impoverishing	0	20%
Renewal	Impoverishing	Renewal	0	10%
Renewal	Impoverishing	Improver	0	0
Renewal	Renewal	Impoverishing	10%	0
Renewal	Renewal	Renewal	10%	20%
Renewal	Renewal	Improver	10%	0
Renewal	Improver	Impoverishing	0	0
Renewal	Improver	Renewal	0	0
Renewal	Improver	Improver	0	10%
Improver	Impoverishing	Impoverishing	0	20%
Improver	Impoverishing	Renewal	0	0
Improver	Impoverishing	Improver	0	0
Improver	Renewal	Impoverishing	0	0
Improver	Renewal	Renewal	0	10%
Improver	Renewal	Improver	0	0
Improver	Improver	Impoverishing	10%	0
Improver	Improver	Renewal	10%	0
Improver	Improver	Improver	0	10%

3.4.2 Scenarios constrains – three different farmers

Whit the aim to define the crop diversification and economic impacts of public policies and private supply chain initiatives on the real farms, we introduced three different production reconstructed scenarios and so three different farmers entrepreneurships' approach: Pure farmer; CAP farmer; CAP+CDM farmer.

<u>Pure Farmer</u>

The farmer is not involved in any production scheme. Therefore, his entrepreneurial choices are dictated by the objective of maximizing income and maintaining land capital. So, he doesn’t have any constrains in crop planning. This is only based on agronomic features, technical knowledge, and machinery.

CAP farmer

The farmer is involved in CAP greening payments production scheme. He decides to receive payments deriving from the Common Agricultural Policy (CAP) promoted by the European Union, following the EU regulation 1307/2013. These payments are, concerning the farm’s case studies, based on a set of standard requirements defined at EU level for obtaining different kinds of incomes [2].

$$CAP = CapB + CapG + CapC$$

Basic payments (CapB)

The basic payment ensures basic income support for farmers engaged in agricultural activities. The BPS works on the basis of payment entitlements distributed to farmers. The general rule was that each eligible hectare gave right to one entitlement. All entitlements allocated to a farmer have the same value, but differences in the value of entitlements may exist between farmers. For the farms involved in the case studies we use the basic title value coming from the national SIAN system (Consultazione Pubblica Registro Titoli Pac 2015 – 2020).

Greening payments (CapG)

It is a substantial addition to the instruments of the CAP basic payments, crosscompliance and voluntary rural development measures, dedicated to environmental and climate issues. Farmers receive the green direct payment if they can show that they comply with three obligatory practices which are good for the environment (soil and biodiversity in particular) and for climate. The greening conditions to reach in compliance for farms typologies involved in the case study are:

- Crop diversification: the rules stipulate that farm with more than 10 ha of arable land have to grow at least two crops, while at least three crops are required on farms with more than 30 ha of arable land. Furthermore, the main crop may not cover more than 75% of the arable land. The sum of the first and second crops per area must not exceed 95% of the arable land.

- Ecological Focus Area: farmers with arable land exceeding 15 ha must ensure that at least 5% of their land is an ecological focus area. Ecological focus areas may include different kind of features linked to landscapes, grasslands or improving biodiversity crops. For case study farms, located in an area characterized by the production specialization of high-income arable crops, we have chosen to introduce the EFAs with nitrogen fixing crops.

For greening constrains “crop” means: a) a crop belonging to any of the different genera defined in the botanical classification of crops; b) a crop belonging to any of the species in the case of Brassicaceae, Solanaceae and Cucurbitaceae; c) land left fallow; d) grass or other herbaceous forage plants.

Coupled payments (CapC)

The farmers receipt of a direct payment to produce a specific product. In the case studies area the coupled payments, declared by the Italian Ministry of Agriculture, are for soy, rice, sugar beet and tomato.

<u>CAP+Cdm farmer</u>

An entrepreneurial factor linked to supply chain initiatives is added. The farmer is involved in the case study supply chain initiative: Carta del Mulino project promoted by Barilla (CdM). Into this standard, two rules involve strong agroecological principals:

- crop rotation with three different crops as minimum. One of those crops must be a nitrogen fixers crop or an oil crop. Only 1 year of replanting of the same crop.
- at least 3% of wheat utilized agricultural area, must be dedicated to flower strips.

The business tool, identified to enhance CdM scheme adoption by the farmers, is a premium price paid for wheat cultivated in compliance with those rules. Those Cdm rules are based on strong agroecology principals: promote the crop diversification and the polycultures whit a large crop rotation and by using nitrogen fixers crops and oil crops; promote the polycultures and the diversification with the flower strips; promote the economic well-being with the business tool identified by the agro-industry.

In the data processing of the CAP + CDM farmer, costs and benefits deriving from the adoption of the CdM production scheme were considered. So, for each hectare of soft CdM wheat produced we: add cultivation cost of the flower strips; decreased yield based on the area of soft wheat lost for flower strips area; add the premium price perceived by the farms (€/ton).

3.5 Data and crops selection

The decision support tool was set up in solving the UAA crop management by simulating "experience of the past years" provided by the individual farmer. From the interviews carried out during the surveys, it emerged that the farmer chooses the crops to be included in his crop plan thanks to the experience of past years essentially based on: yields and prices (market); crops performances in their cultivation areas; work capacity (machines, equipment, labour).

Starting from this, we have reconstructed, for yields (Y) and prices (Pr), the "farmer data experience" for six years. For doing this, we have used the mean value between the observed data (2019 – 2020) and official datasets values (2015-2018).
The prices (Pr) database was reconstructed by using: annual prices available on official commodities exchange most used for the definition of Italian annual goods price (AGER – Bologna); prices annually fixed by contracts for industrial crops: tomato "Contratto Quadro"; sugar beet "Cooperative CO.PRO.B"; official Italian Ministry of Agriculture decree (Decreto prezzi MIPAAF). The following table shows the data collected and the source of data used for every single crop (Table 13).

Table 13 – Price data collection for the years 2015 – 2018.

CROP	2015	2016	2017	2018	Source
SOFT WHEAT	225	201	222	213	AGER Bologna
CORN	166	178	182	183	AGER Bologna
SILAGE MAIZE	33	33	33	32	AGER Bologna
SORGUM	171	192	187	179	AGER Bologna
DURUM WHEAT	292	206	228	216	AGER Bologna
BARLEY	182	175	169	197	AGER Bologna
TRITORDEUM	315	315	315	315	MIPAAF - DECRETO PREZZI
TRITICALE	31	31	33	27	MIPAAF - DECRETO PREZZI
SUGAR BEET	34	37	38	35	COPROB
TOTMATO	92	81	81	80	COTR. QUADRO
SOY	377	362	400	356	AGER Bologna
CHICKPEA	578	828	982	422	BORSA MERCI ALTAMURA
PEA	340	236	225	209	AGER Bologna
RAPESEED	381	360	360	364	MIPAAF - DECRETO PREZZI
SUNFLOWER	298	314	285	291	AGER Bologna
GRASS	133	138	140	140	MIPAAF - DECRETO PREZZI
LOLIUM	133	138	140	140	MIPAAF - DECRETO PREZZI
VETCH	156	145	131	136	MIPAAF - DECRETO PREZZI
ALFALFA	80	76	96	95	AGER Bologna
STRAW	44	36	37	45	AGER Bologna

Yields (Y) are taken by the National Agricultural Information System (SIAN). The system records all the crops yields for year and municipality. So, the data used are on municipality scale for every single farm[6]. For the CAP payments (CapB; CapG) and Rdps payments (RdpA) we use the real farm's data for all the years. For soy, sugar beet and tomato we added the CAP coupled support payments (CapC) declared by the Italian Ministry of Agriculture for the year 2019.

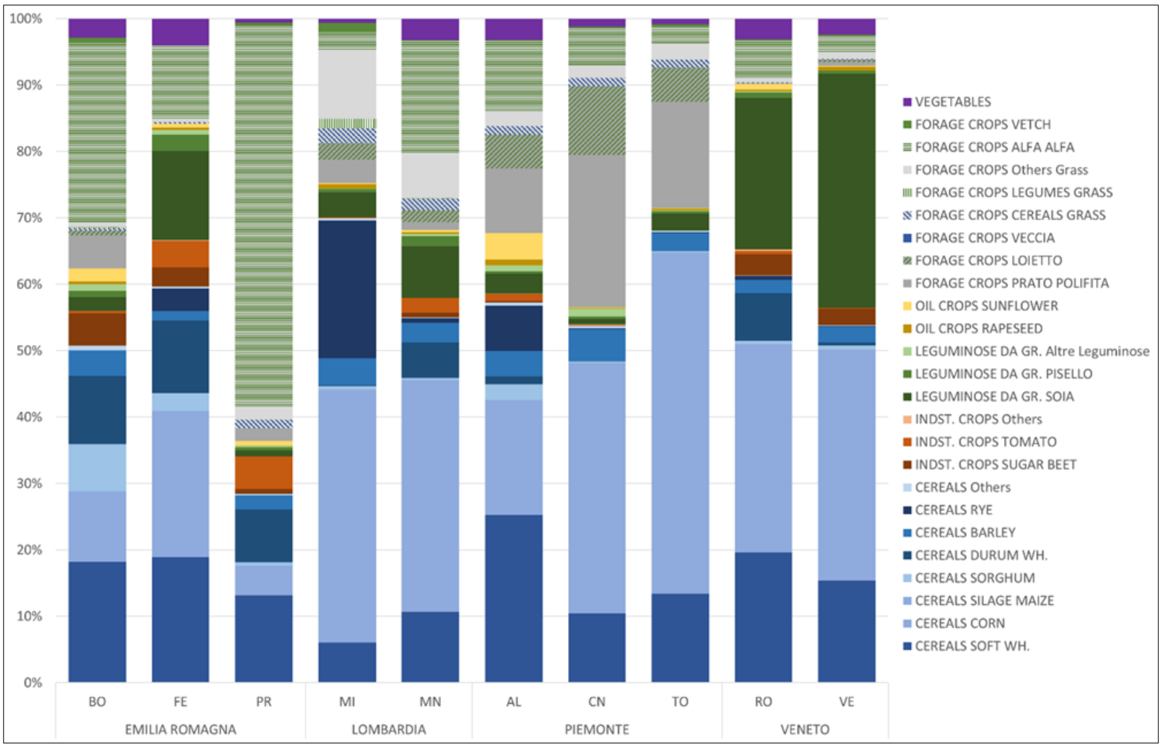
For the cultivation costs, composed by technical inputs (TI) and cultivation operation costs (CO) we used the real farm's value collected during surveys. The costs of mechanization and the costs of technical means do not have large price variations, so we can use the observed data for all the years. In case of new introduction of a crop we use: the mean value of province if the new crop is in the ordinary province land use; the highest if the new crop is not used in the ordinary province land use.

Within the model, a set of crops have been inserted for each farm to be allocated to the arable land. The crop set for all farms includes all crops already grown by farms for the years of data collection. In addition to these, other crops have been added that

[6] Sian – Consultazione Rese Benchmark - https://www.sian.it/consRese/paiRicerca.do

farms could potentially grow. So, starting from land use analysis coming from 2019 ISTAT database for annual crops (1st year of survey) (Graph 9), we introduce new crops by following these assumptions:

- the introduced crops are only those that technically can growth by farmers. Crops that require specific technical knowledge or machinery were not considered as possible uses (industrial crops; forages)
- insertion of grain legumes crops and oil crops most represented in the farm's provinces for reach in compliance to the case study crop rotation rules (Carta del Mulino).



Graph 9 - Land use analysis coming for the farm's provinces. Source of data: ISTAT 2019

CHAPTER 4
RESULTS AND DISCUSSION

In this chapter we show the results of the data elaboration as presented in the material and methods. The following paragraphs shows the impact of the public policies and the case study private initiative the farms involved in surveys. First, we present results regarding the impacts on production costs for CdM's soft wheat for the case study's farms for the year 2019. Those results can show the impact of the private initiative selected af "field level". Secondly the results coming from data elaboration of the tool created (Cf. 3.4) can identify impacts of public policies and private initiatives (Carta del Mulino case study) and how those can "pull", or "push" the case study's farms to diversify their cropping systems. The elaboration carried out by the experimental decision support tool can identify quantitative result (€/ha) and qualitative results (farm's crop diversifications).

4.1 First results: impacts of private initiative at field level

In order to provide a complete overview, we considered it important to show the impact that the introduction of private initiative has had for the year 2019 at "field level". The "field level" take into account only the farm's UAA utilized for Soft Wheat involved in CdM scheme. Following the first point of the rule two, the soft wheat area is connected to the flower strip's area: 3% of wheat utilized agricultural area.

The CdM practices costs were estimated following a methodological approach already used in payments definition for Common Agricultural Policy (CAP) agro-environmental- climate measures. EU guidelines suggest to define the amount of compensative payments as all or part of the additional costs and income foregone, resulting from the commitments made. So, the impacts are estimated in € per ton by analysing the difference between two scenarios: Cdm vs Ordinary. The CdM scenario consider the real sustained costs for the soft wheat and the flower strip per ton of production. The analysis of cultivation costs (CC) and productions (Tot Prod) were used to obtain the real costs incurred by farmers to produce a ton of CdM soft wheat [1] and the additional costs coming from flower strips management [2].

$$Cdm\ Soft\ Wheat\ Cost\ (€/t) = \frac{CC\ Soft\ Wheat_{\ CdM}(€) +\ CC\ Flower\ Strip_{\ CdM}\ (€)}{Tot\ Prod_{\ CdM}\ (t)} \quad [4.1]$$

$$Flower\ Strip\ Cost\ (€/t) = \frac{CC\ Soft\ Wheat_{\ CdM}\ (€)}{Tot\ Prod_{\ CdM}\ (t)} \quad [4.2]$$

The evaluation of the income foregone it was possible by the introducing of the ordinary scenario (Ord). This is a reconstruct scenario based on the following assumptions:

- the flower strip's UAA is used for soft wheat cultivation.
- the cultivation technique is the same of CdM ;
- the ordinary price is obtained without considering the CdM premium price quota.

The following formulas are used to obtain the income foregone coming from the adoption of Cdm production scheme.

$$Tot\ Prod_{\ Ord}(t) =\ Yield\ Soft\ Wheat_{CdM}\left(\frac{t}{ha}\right) X \left(UAA\ Soft\ Wheat_{CdM} + UAA\ Flower\ Strip_{CdM}(ha)\right) \quad [4.3]$$

$$Foregone\ Yield\ (t) =\ Tot\ Prod_{\ Ord}(t) - Tot\ Prod_{\ CdM}\ (t) \quad [4.4]$$

$$Income\ foregone\ (€/ton) = \frac{Foregone\ Yield\ (t)\ X\ Price_{\ Ord}(€)}{Tot\ Prod_{\ CdM}\ (t)} \quad [4.5]$$

The following table show impacts on production costs for CdM's soft wheat at field level (table 14). Those costs compared whit the real premium price perceived by the farmers (CdM Pr. Price) can show the real revenues coming from the adoption of this private initiatives at "field level".

Table 14 - Impacts on production costs and revenues coming from the CdM adoption at field level.

Region	Prov	Farm Code	Cdm Soft Wheat Cost (€/t) [4.1]	Flower Strip Cost (€/t) [4.2]	Income foregone (€/t) [4.5]	Total cost CdM TC (€/t) [4.2]+[4.5]	CdM Pr. price PP (€/ton)	PP - TC (€/ton)	Costs incidence on PP-TC/ PP
Emilia Romagna	BO	BO_1	152,28	2,40	6,05	8,45	20,00	11,55	42%
	BO	BO_2	134,28	2,91	6,57	9,48	20,00	10,52	47%
	BO	BO_3	156,84	2,34	6,15	8,49	20,00	11,51	42%
	FE	FE_1	155,65	2,61	6,08	8,68	20,00	11,32	43%
	FE	FE_2	135,38	1,27	6,68	7,95	30,00	22,05	26%
	FE	FE_3	124,76	1,64	5,70	7,34	30,00	22,66	24%
	FE	FE_4	166,20	2,35	6,66	9,01	30,00	20,99	30%
	PR	PR_1	144,17	1,90	6,70	8,60	25,00	16,40	34%
Lombardia	MI	MI_1	194,04	1,84	7,82	9,66	10,00	0,34	97%
	MI	MI_2	210,16	2,64	10,38	13,02	10,00	-3,02	130%
	MN	MN_1	130,34	1,93	6,36	8,28	15,00	6,72	55%
	MN	MN_2	150,04	1,70	6,27	7,97	15,00	7,03	53%
	MN	MN_3	113,33	1,72	6,58	8,30	15,00	6,70	55%
Piemonte	AL	AL_1	165,18	1,13	6,76	7,89	20,00	12,11	39%
	AL	AL_2	125,91	1,59	7,52	9,11	20,00	10,89	46%
	AL	AL_3	131,67	2,68	6,64	9,31	20,00	10,69	47%
	AL	AL_4	165,42	1,69	6,45	8,14	20,00	11,86	41%
	CN	CN_1	174,02	1,79	5,05	6,85	20,00	13,15	34%
	CN	CN_2	171,01	1,82	5,70	7,52	20,00	12,48	38%
	TO	TO_1	145,35	1,85	6,63	8,48	20,00	11,52	42%
Veneto	RO	RO_1	211,28	3,27	6,03	9,30	30,00	20,70	31%
	RO	RO_2	175,01	1,66	5,69	7,35	20,00	12,65	37%
	VE	VE_1	180,67	1,82	5,10	6,92	20,00	13,08	35%

Looking at those results the costs impact of Cdm soft wheat production are different per region and per province. The differences are based on costs of flower strip's seeds, and different cost of technics adopted. Emilia Romagna mean value is 8,50 €/t, lower than Lombardia 9,45 €/t. Piemonte total impact mean value is 8,20 €/t and Veneto 7,86 €/t.

Those costs results compared whit the premium price perceived by farmers, can show the real revenues at field level. The premium price is different trough regions and provinces. It depends from business contract between miller and elevators. However, all the provinces have farms whit positive revenues. Only in Milano (MI) we find lower and negative values. These are connected to the high production costs and a low premium price. The evaluation of revenues highlights the total cost impact as a "breakeven point" for the farms: if the premium price is lower than this value there are not positive revenues for farms involved in CdM scheme.

The last column shows the incidence of costs on the premium price perceived for the single farm. Is very interesting observing the incidents is at least 75% for Lombardia, Piemonte 40% and 35% in Emilia Romagna and Veneto. So, the business contract used in Lombardia is not so strong in terms of economic sustainability for farms. From those results we can understand the strongness of the private initiative if we look only at soft wheat level. But as we have seen the private initiative involve the farm's arable land planning for 5 years. For evaluate this impact we have used the specific crop rotation tool model.

4.2 Impacts of public policies and private initiative at farm level

This paragraph illustrates and comments on the output results of the experimental tool created for the research carried out. The model, set up with the agronomic and scenario constraints seen previously (Cf. 3.4.1 and 3.4.2), provides two types of output. Whit the main objective of maximization of the net profit the model gives: quantitative output expressed like the best Gross Margin coming from the cultivation of arable land's farm for 5 years; qualitative results showing the crop rotation applied in 5 years for each ha of arable land on farms.

4.2.1 Quantitative results

The table below shows the economic results carried out by the prevision tool the data described above (Table 15). For every farm are reported the best Gross Margin results for every farmer scenario: Pure; CAP; CAP+CdM. The Gross Margin is reported in: total 5 years value (€); 5 years value per hectare (€/ha); annual average value per hectare (€/ha).

Table 15 – Economic results. Best Gross Margin results for every farmer scenario: Pure; CAP; CAP+CdM

Framer Scenario			Pure			CAP			CAP+CDM			Δ GM annual avarage		
Region	Farm	UAA	GM total 5 years	GM ha 5 years	GM ha annual avarage	GM total 5 years	GM ha 5 years	GM ha annual avarage	GM total 5 years	GM ha 5 years	GM ha annual avarage	CAP	CAP+ CDM	CDM
		ha	*€*	*€/ha*	*€/ha*	*€*	*€/ha*	*€/ha*	*€*	*€/ha*	*€/ha*	*€/ha*	*€/ha*	*€/ha*
					[1]			[2]			[3]	[4]=[2]-[1]	[5]=[3]-[1]	[5]-[4]
Emilia Romagna	BO1	161	494.903	3.074	615	1.033.833	6.421	1.284	1.086.321	6.747	1.349	669	735	65
	BO2	229	667.741	2.916	583	1.670.886	7.296	1.459	1.723.333	7.525	1.505	876	922	46
	BO3	72	186.915	2.596	519	340.865	4.734	947	347.632	4.828	966	428	446	19
	FE1	177	653.204	3.690	738	1.089.875	6.157	1.231	1.092.433	6.172	1.234	493	496	3
	FE2	89	285.202	3.205	641	454.571	5.108	1.022	465.987	5.236	1.047	381	406	26
	FE3	23	89.596	3.895	779	136.005	5.913	1.183	140.253	6.098	1.220	404	440	37
	FE4	27	102.535	3.798	760	171.966	6.369	1.274	177.139	6.561	1.312	514	553	38
	PR1	29	174.676	6.023	1.205	159.308	5.493	1.099	166.551	5.743	1.149	-106	-56	50
Lombardia	MI1	53	103.949	1.961	392	256.200	4.834	967	257.995	4.868	974	575	581	7
	MI2	51	127.934	2.509	502	288.669	5.660	1.132	290.319	5.693	1.139	630	637	6
	MN1	86	980.863	11.405	2.281	1.085.012	12.616	2.523	1.092.714	12.706	2.541	242	260	18
	MN2	66	210.945	3.196	639	410.982	6.227	1.245	418.645	6.343	1.269	606	629	23
	MN3	84	1.047.808	12.474	2.495	1.319.890	15.713	3.143	1.418.083	16.882	3.376	648	882	234
Piemonte	AL1	154	1.069.265	6.943	1.389	1.496.261	9.716	1.943	1.588.214	10.313	2.063	555	674	119
	AL2	120	553.195	4.610	922	1.186.594	9.888	1.978	1.256.406	10.470	2.094	1.056	1.172	116
	AL3	54	127.296	2.357	471	254.348	4.710	942	260.300	4.820	964	471	493	22
	AL4	84	236.728	2.818	564	380.739	4.533	907	402.581	4.793	959	343	395	52
	CN1	62	223.111	3.599	720	501.915	8.095	1.619	458.095	7.389	1.478	899	758	-141
	CN2	34	103.718	3.051	610	175.719	5.168	1.034	177.564	5.222	1.044	424	434	11
	TO1	19	75.010	3.948	790	106.747	5.618	1.124	107.852	5.676	1.135	334	346	12
Veneto	RO1	49	69.894	1.426	285	186.723	3.811	762	189.916	3.876	775	477	490	13
	RO2	134	2.246.993	16.769	3.354	2.512.785	18.752	3.750	2.702.265	20.166	4.033	397	680	283
	VE1	211	735.681	3.487	697	1.506.860	7.142	1.428	1.669.042	7.910	1.582	731	885	154

The differences between the three scenarios in terms of GM annual average per hectare, have made possible to identify the action of the economic levers of public and private initiatives on the farm's gross income (last three columns).

All the results about CAP seems to pull the farmer to a new agroecological approach. The results show differences between the farms, but we have most of positive results in five years [4]. In Emilia Romagna the CAP vector pulls the farmers to diversify their cropping systems whit an average value of positive Gross Margins of + 457 €/ha for five years. The bests result is for Bologna province's farms (BO1 and BO2) where we found the higher values (+669 €/ha and +876 €/ha). Those results are connected whit the coupled subsidies paid for sugar beet and soy. In fact, in these farms in the CAP scenario we find a great surface dedicated do sugar beet. Also, in Ferrara provinces we find all positive values, but low compared to Bologna (about 448 €/ha). The positive value is linked to the soy cultivation and the CAP subsidies paid for this. The only observation that we have in Parma shows a negative value: -106 €/ton. This negative value is linked to the cultivation of tomato. In the Pure farmer scenario, most of the arable land is dedicated to tomato cultivation because this has the best results in the province. The farm to comply to the Greening CAP rules must diversify their cropping system by compromising his revenues. So, the coupled payments paid for tomato cultivation can't compensate the losses caused by the CAP crop diversification practices. In Lombardia the CAP vector pulls the farmers to diversify their cropping systems whit an average value of positive Gross Margins of + 540 €/ha for five years. All the farms show positive values. We find the best value in MN3: +648 €/ha. Also, in this case we find the extreme value linked to the tomato cultivation, but in positive. In this case we find an improvement of incomes caused by the CAP coupled payments paid for tomato cultivation. So, the CAP promotes the crop diversification and the cultivation of high-income industrial crops. In Piemonte the CAP vector pulls the farmers to diversify their cropping systems whit an average value of positive Gross Margins of + 583 €/ha for five years. All the farms show positive values. We find the best value in AL2: +1056 €/ha. Also, in this case the positive values are linked to the cultivation of tomato and to the CAP coupled payments paid for this. The only observation in Torino province has the lower value: +334 €/ha. The farm also in the Pure farmer scenario presents a high specialization in soy cultivation. In CAP scenario this can have more incomes linked to the CAP coupled payments paid for it. In Veneto we have only three observations. However, it is possible to identify that CAP vector pulls the farmers to diversify their cropping systems whit an average value of positive Gross Margins of + 583 €/ha for five years. The best value is in Venezia province with +731 €/ha. Also, in this case the best value is linked to industrial crop cultivation. The farm has lot of arable land dedicated to sugar beet cultivation, and the CAP couple subsidies linked to it can improve revenues for the farm also in CAP crop diversification rules compliance.

All the results about “Carta del Mulino” private initiative seems to pull the farmer to a new agroecological approach also in 5 years of crop rotation. The results show differences between the farms, but we have most of positive results in five years [6]. In Emilia Romagna the CDM vector pulls the farmers to diversify their cropping systems whit an average value of positive Gross Margins of + 35 €/ha for five years. In Bologna province we can observe the best value: BO1 +65 €/ha for five years. In Ferrara province we find the worst value + 3€/ha for five years. In this case the CdM adoption by farm improve the crop diversification of the system, but the business tool (premium price) can’t compensate this transition. It’s very interesting the case of Parma where the private initiative mitigates the negative value generated by the CAP constrains. So, in this case the private initiative can private initiative manages to smooth out the income gap generated by public policy action. Also in Lombardia the CDM vector pulls the farmers to diversify their cropping systems whit an average value of positive Gross Margins of + €/ha for five years. In Piemonte the CDM vector pulls the farmers to diversify their cropping systems whit an average value of positive Gross Margins of + €/ha for five 27 years. However, we can find great difference between farms. The best values are in Alessandria provinces farm’s: AL1 +119 €/ha. In this case the private initiative promotes a crop rotation in the following years that can improve the Gross Margin of the farm. In Cuneo CN1 we can observe a negative value -141 €/ha fort five years. In this case the mandatory crop rotation proposed by the private initiative have a negative action on the gross margin of the farms. This is linked to the cultivation of corn that shows high incomes in all the years. The best value in all the case study farms in obtained in Rovigo: RO2 +283 €/ha for five years. Also in this case the private initiative promotes a crop rotation in the following years that can improve the Gross Margin of the farm.

Finally, the results shows that CAP vector pull and push farmers to diversify their cropping systems by the greening rules. But is also important the convergence between greening payments (CapG) and coupled payments (CapC) resulted. In farms where we find crops with coupled payments subsidies, we find also the main strongness to comply whit greening rules, so to diversify cropping systems. The private initiative action goes to the same direction whit differences in action linked to crop rotation constrains that can affect the Gross Margin of the far4ms for five years. In most of the observed results the business tool promoted by Barilla can pull the farms to the agroecology approach considering five years of crop rotation.

4.2.2 Qualitative results

The decision support tool results from the three scenarios have made possible to identify the crop diversification at UAA level promoted by public initiatives and private initiatives. For each single farm, a graphic rendering has been developed capable of identifying the crop rotation applied for each single hectare of cultivated land. This elaboration was carried out for all three proposed scenarios: Pure farmer; CAP farmer; CAP+Cdm farmer. The farm’s UAA graphic rendering allow to identify the crop diversification promoted by the CAP and the CdM private initiatives. The figures presented in the following pages shows the UAA graphic rendering evolution for the five years for the case study farms. The columns show the years considered by the systems (5 years), and each row represents a hectare of farm’s UAA.

The system can take second harvest crops into consideration by dividing the year period into two columns: i) first semester for crops harvested by July; ii) second semester for crops harvested during the second semester. The second harvest crop is inserted in the crop rotation plan only for the farms that already grow it. With the aim of considering the technical possibilities of being able to sow and harvest the second crop, the UAA dedicated to it was set with a maximum of hectares equal to those sown in the first year. The system also provides a maximum repetition of the single crop linked to its technical success in the areas considered. The maximum repetition was set based on interviews carried out on farms. For all crops, a maximum repetition of 3 years is foreseen, except for industrial crops where it passes to two (tomato; sugar beet).

In the following pages are presented all the results for every farm whit graphic rendering ad a brief comment on it. To better understand the farm’s graphic rendering we have to taking into account the following picture as al legend to read it (Figure 8).

Figure 8 -Crop's chromatic legend.

CDM SOFT WHEAT + FLOWER STRIP	
SOFT WHEAT.	
CORN	
SILAGE MAIS	
SORGHUM	
SILAGE SORGHUM	
DURUM WHEAT	
BARLEY	
RYE	
TRITORDEUM	
TRITICALE	
SUGAR BEET	
TOMATO	
SOY	
SOY II° HARVEST	
CHICKPEA	
PEA	
RAPESEED	
SUNFLOWER	
GRASS	
LOLIUM	
VETCH	
ALFALFA	

*Figure 9 - **BO1** UAA graphic rendering for the three considered scenarios*

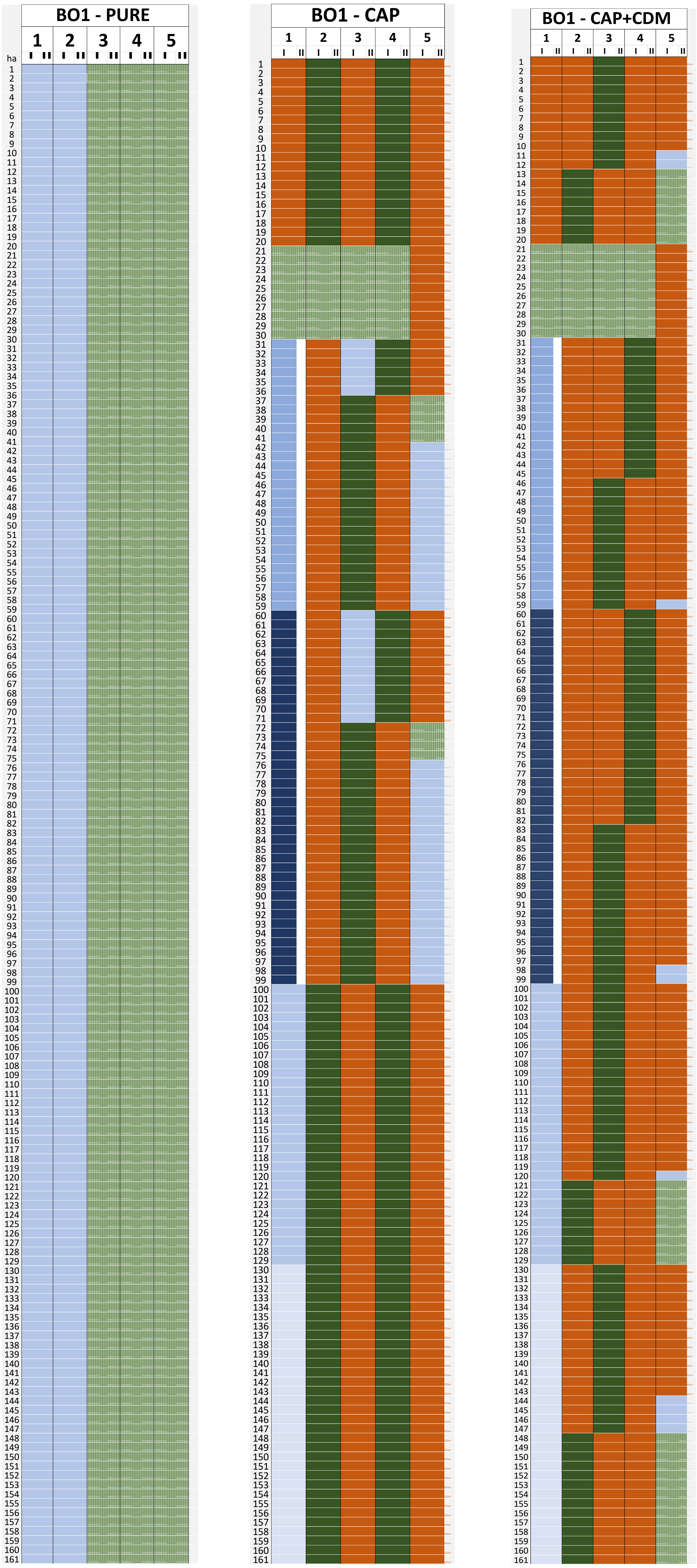
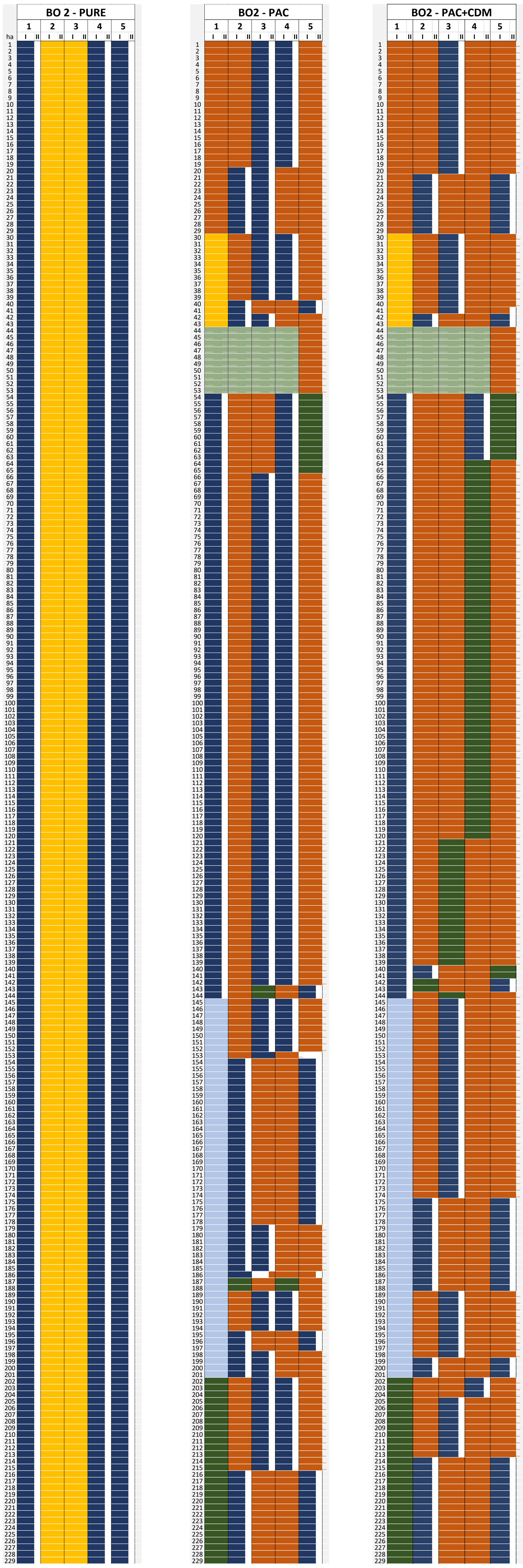


*Figure 10 – **BO2** UAA graphic rendering for the three considered scenarios*



Emilia Romagna - BO1

The Pure farmer scenario shows a monoculture result. In all the years the farm's UAA is dedicated to one crop and in particular the most high-income crops: corn for two years followed by alfalfa. The CAP constrains add an important diversification of the UAA. We find the introduction of two crops in an equilibrated crop rotation: soy and sugar beet. The introduction of this crops is linked to the coupled CAP subsidies perceived. The CAP adds an improvement of crop diversification through the year and whitin the years. The grain legumes introduction allows to have a virtuous crop rotation. The private initiative action is linked only in the UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverished-renewal-improvement crops.

Emilia Romagna - BO2

The Pure farmer scenario shows a monoculture result. In all the years the farm's UAA is dedicated to one crop and the most high-income crops: first year soft wheat; rapeseed for the following two years and two years of soft wheat. The CAP constrains add an important diversification of the UAA: minimum 4 crops at year. The CAP scenario is characterized by: introduction of sugar beet linked to the coupled CAP subsidies perceived; introduction of soy (grain legumes) only to be in compliance to the CAP greening constrains (5% of UAA). The CAP adds an improvement of crop diversification through the year and by the years. The private initiative action has an important influence in the crop rotation plan. We find Cdm Soft wheat cultivation for all the five years. This is a great result in terms of crop diversification linked to the 3% of soft wheat UAA dedicate to flower strips. In addition to this the private initiative crop rotation constrains enhance the cultivation of grain legumes: 25% of UAA . So, we can observe a good crop rotation based on the succession of impoverishing, renewal and improver crop.

*Figure 11 – **BO3** UAA graphic rendering for the three considered scenarios*

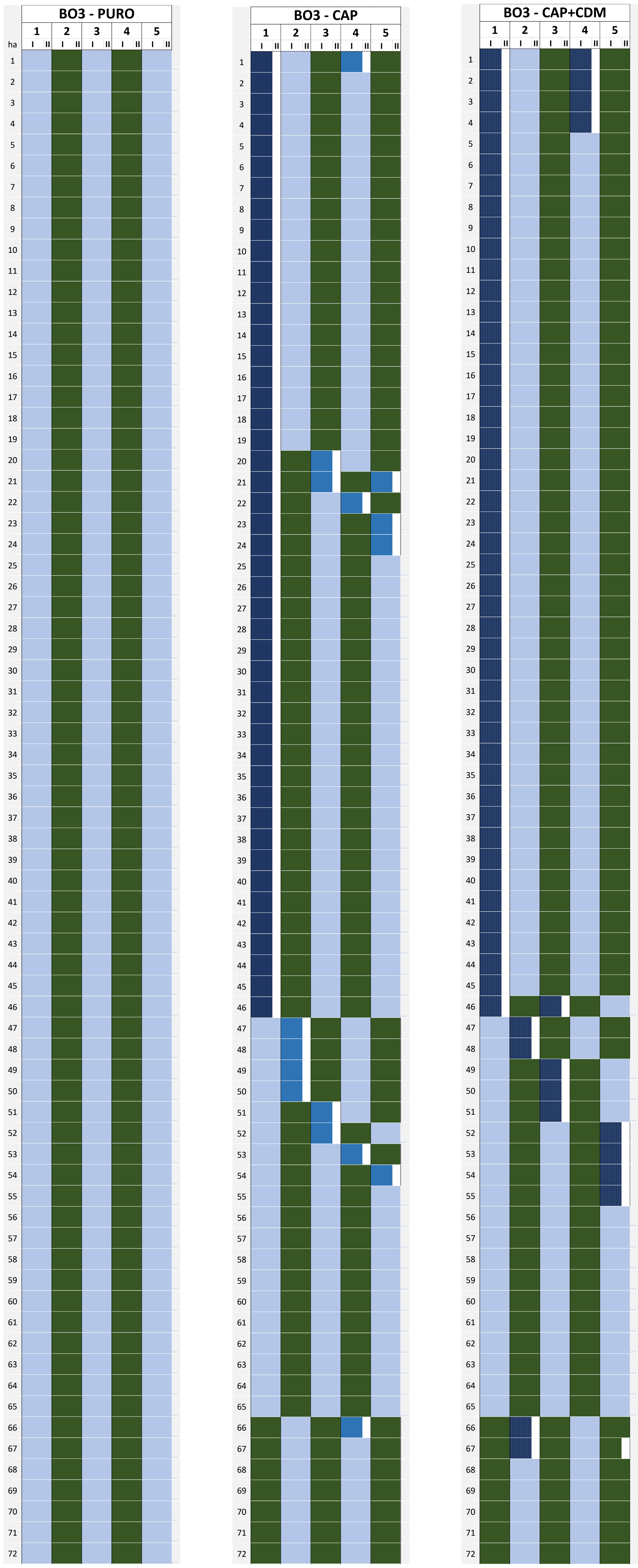
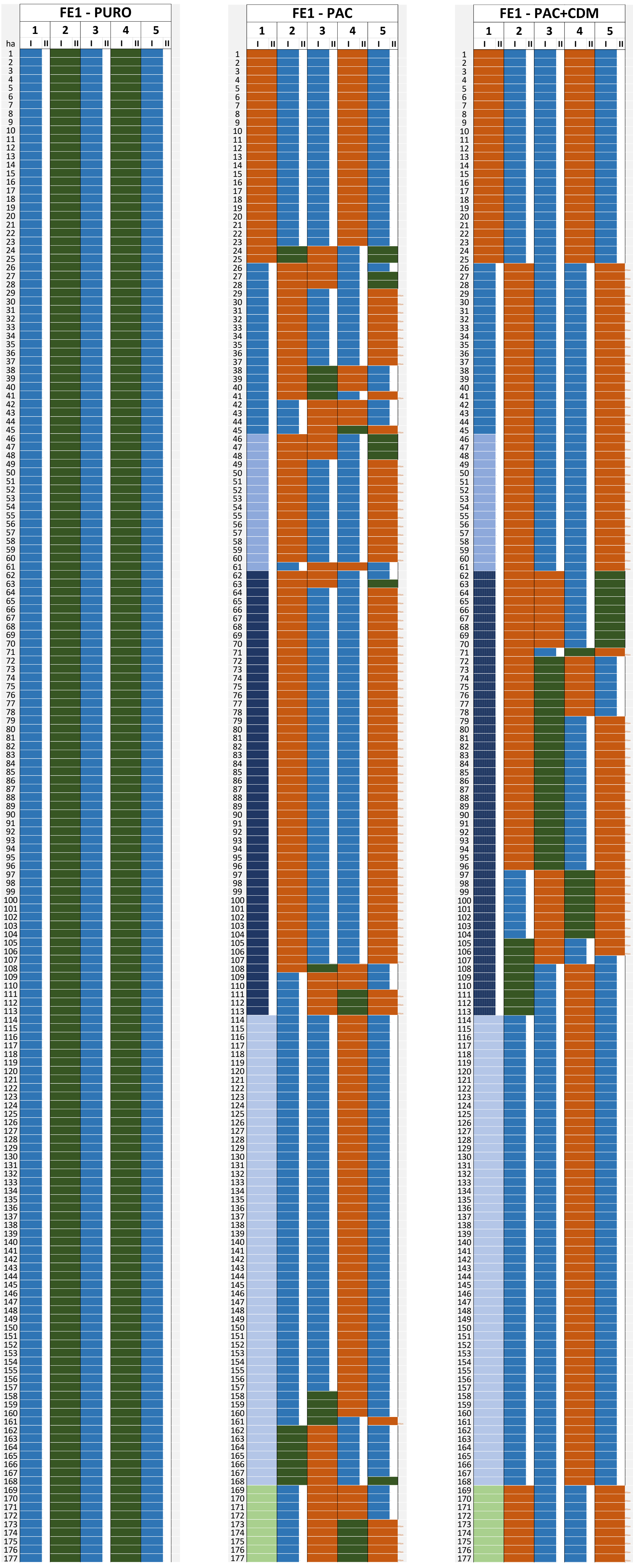


*Figure 12 – **FE1** UAA graphic rendering for the three considered scenarios*



Emilia Romagna - BO3

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of corn and soy. This is linked to the high-income of those two crops. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as the greening constrains rule say. So, we find a high presence of soy linked to the CAP coupled payments (more than 45% starting from the second year) and a crop rotation based on succession of renewal and improvers crops (corn and soy). The private initiative action is linked only to the cultivation of flower strips for 5 years. In fact we can only observe a substitution of soft wheat and durum wheat for the cultivation of Cdm plots.

Emilia Romagna - FE1

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of corn and soy. This is linked to the high-income of those two crops. The CAP scenario shows a different situation. The CAP coupled subsidies improve the sugar beet cultivation and reduce the grain legumes cultivation to the minimum UAA required by greening constrains. In this company we find a turnaround: the CAP promotes industrial cultivation, affecting the virtuous crop rotation present in the pure scenario. The private initiative action is linked only in the UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the insertion of grain legumes. We find a little improvement in soy cultivation in the third year: from 8 ha to 25 ha.

*Figure 13 – **FE2** UAA graphic rendering for the three considered scenarios*

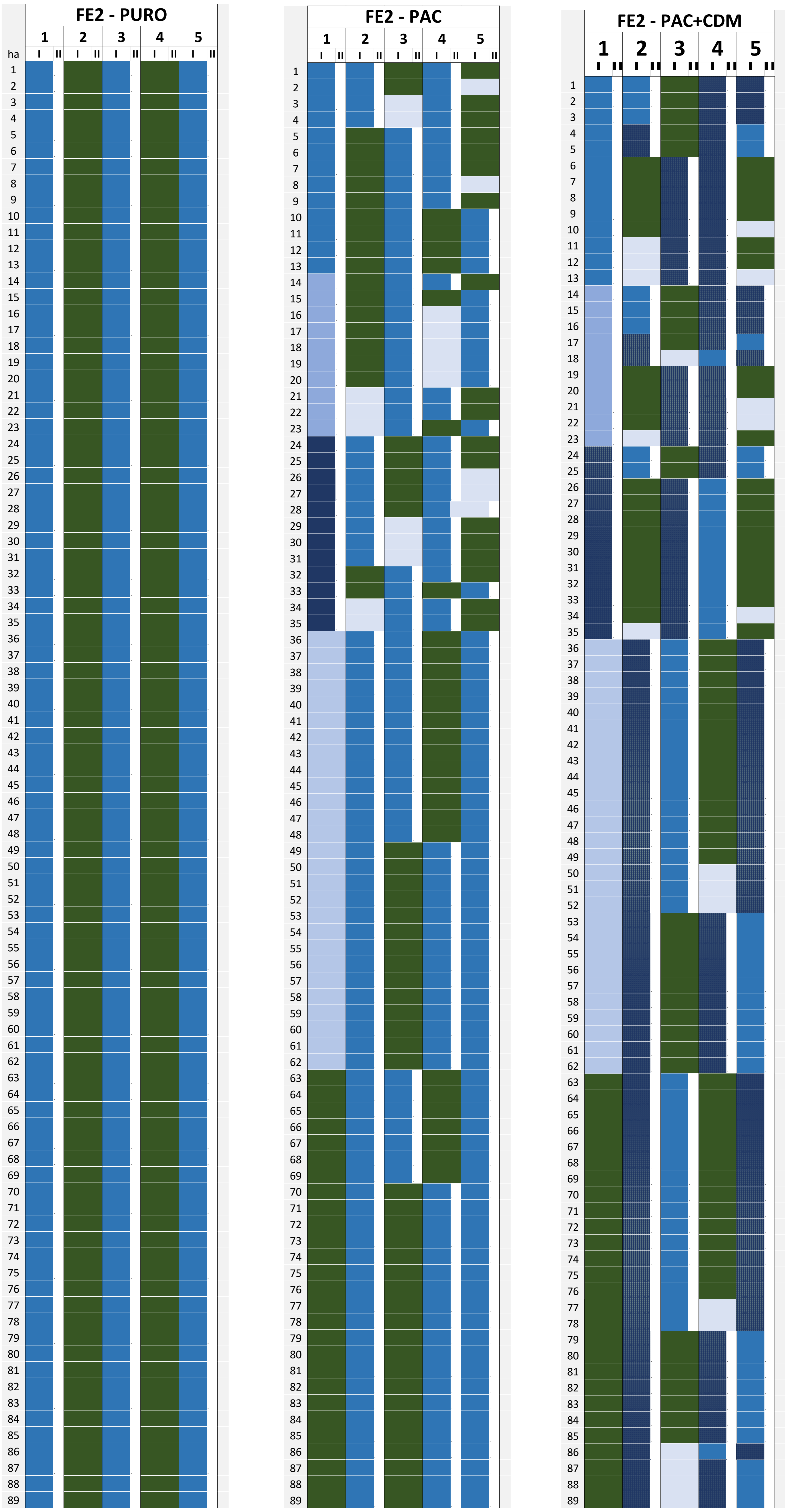
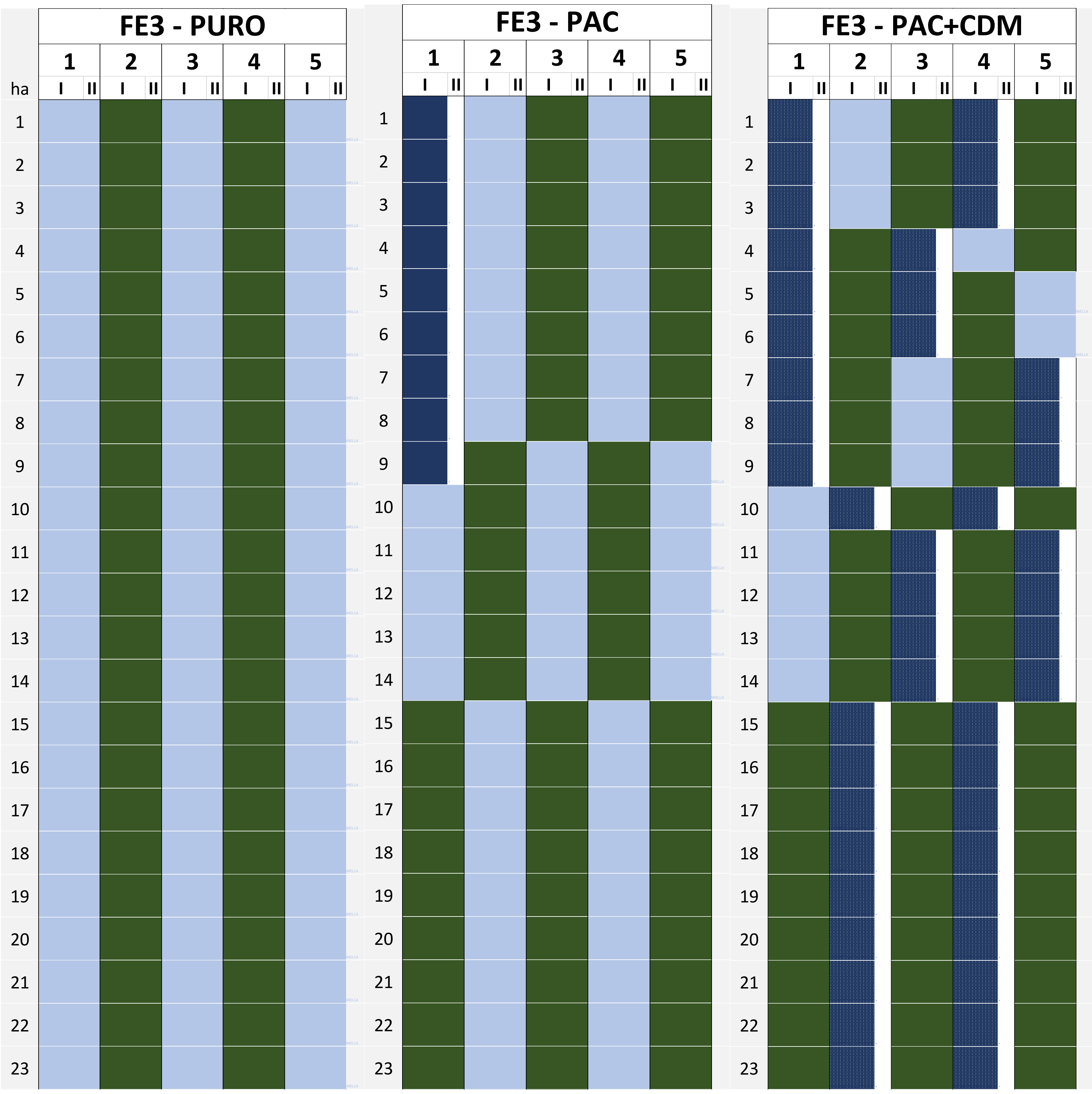


*Figure 14 – **FE3** UAA graphic rendering for the three considered scenarios*



Emilia Romagna - FE2

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of durum wheat and soy. This is linked to the high-income of those two crops. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as the greening constrains rule say. So, we find a high presence of soy linked to the CAP coupled payments (more than 30 %) and a crop rotation based on succession of renewal improvers and impoverishing crops (corn; soy; durum wheat). The private initiative action has an important influence in the crop rotation plan. We find Cdm Soft wheat cultivation for all the five years. This is a great result in terms of crop diversification linked to the 3% of soft wheat UAA dedicate to flower strips. So, we can observe a good crop rotation based on the succession of impoverishing, renewal and improver crop.

Emilia Romagna - FE3

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of corn and soy. This is linked to the high-income of those two crops. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as the greening constrains rule say. So, we find a high presence of soy linked to the CAP coupled payments (more than 25 %) and a crop rotation based on succession of renewal improvers and impoverishing crops (corn; soy; soft wheat). The private initiative action has an important influence in the crop rotation plan. We find Cdm Soft wheat cultivation for all the five years. This is a great result in terms of crop diversification linked to the 3% of soft wheat UAA dedicate to flower strips. So, we can observe a good crop rotation based on the succession of impoverishing, renewal, and improver crop.

*Figure 15 – **FE4** UAA graphic rendering for the three considered scenarios*

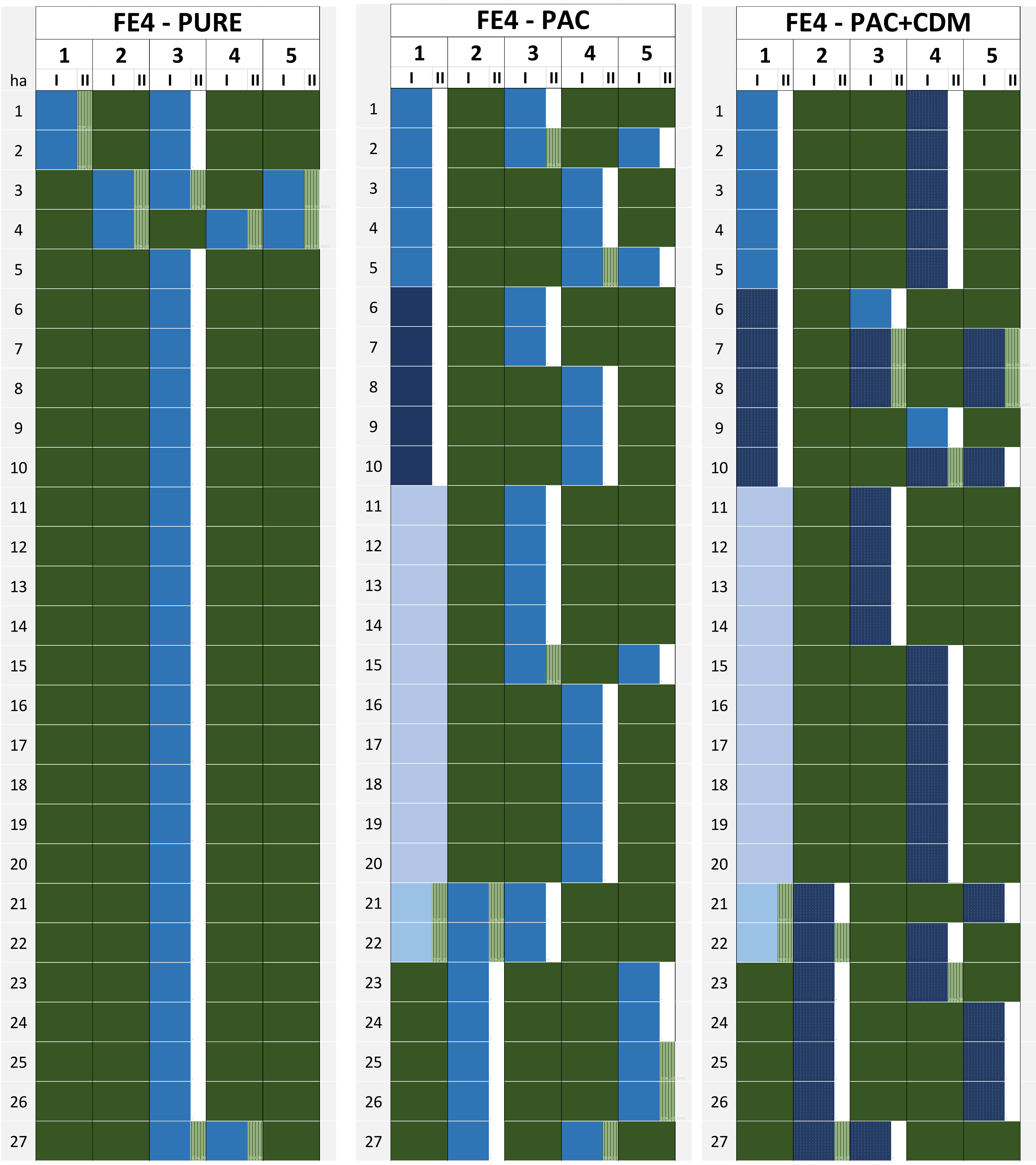
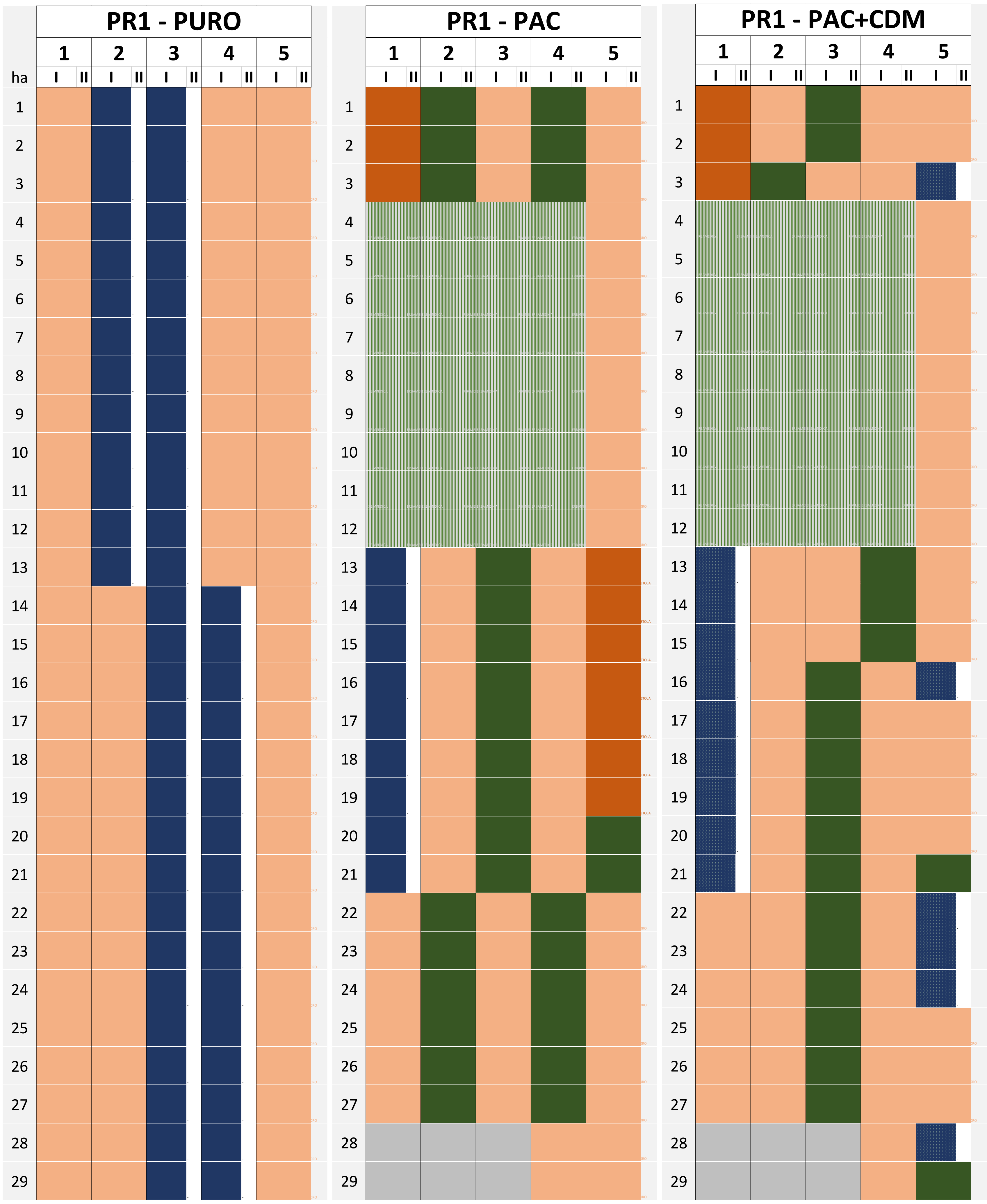


*Figure 16 – **PR1** UAA graphic rendering for the three considered scenarios*



Emilia Romagna - FE4

The Pure farmer scenario shows a monoculture result for the 93% of UAA. Most of the arable land is involved in soy cultivation: 93% for four years. However, through the years we can observe a virtuous crop rotation based on the alternation of soy and durum wheat. This is linked to the high-income of those two crops. The CAP scenario is characterized by the increase of durum wheat presence in all the years, but the crop rotation remains the same. So, in farms where we found an high-income grain legumes cultivation we can have a good corp rotation also in the pure farmer scenario.

Emilia Romagna - PR1

The Pure farmer scenario shows a scenario characterized by a monoculture for 3 years. The first and the fifth have the UAA all involved in tomato cultivation, the third in soft wheat cultivation. In the other years we have the succession between tomato and soft wheat. The high presence of tomato cultivation is linked to the high revenue that have this crop in Parma province. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. We always find a high presence of tomato (30% of UAA as minimum from the second year), but in succession with soy and soft wheat. The introduction of alfalfa in the first year have a repercussion for the following three years. So, whit the CAP constrains we find a more virtuous land use characterized by a crop rotation based on the succession of renewal crop and improver crop. The private initiative action is linked to UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverishing-renewal-improvement crops. We find also a 21% of UAA dedicated to Cdm Soft wheat in the fifth year.

*Figure 17 – **MI1** UAA graphic rendering for the three considered scenarios*

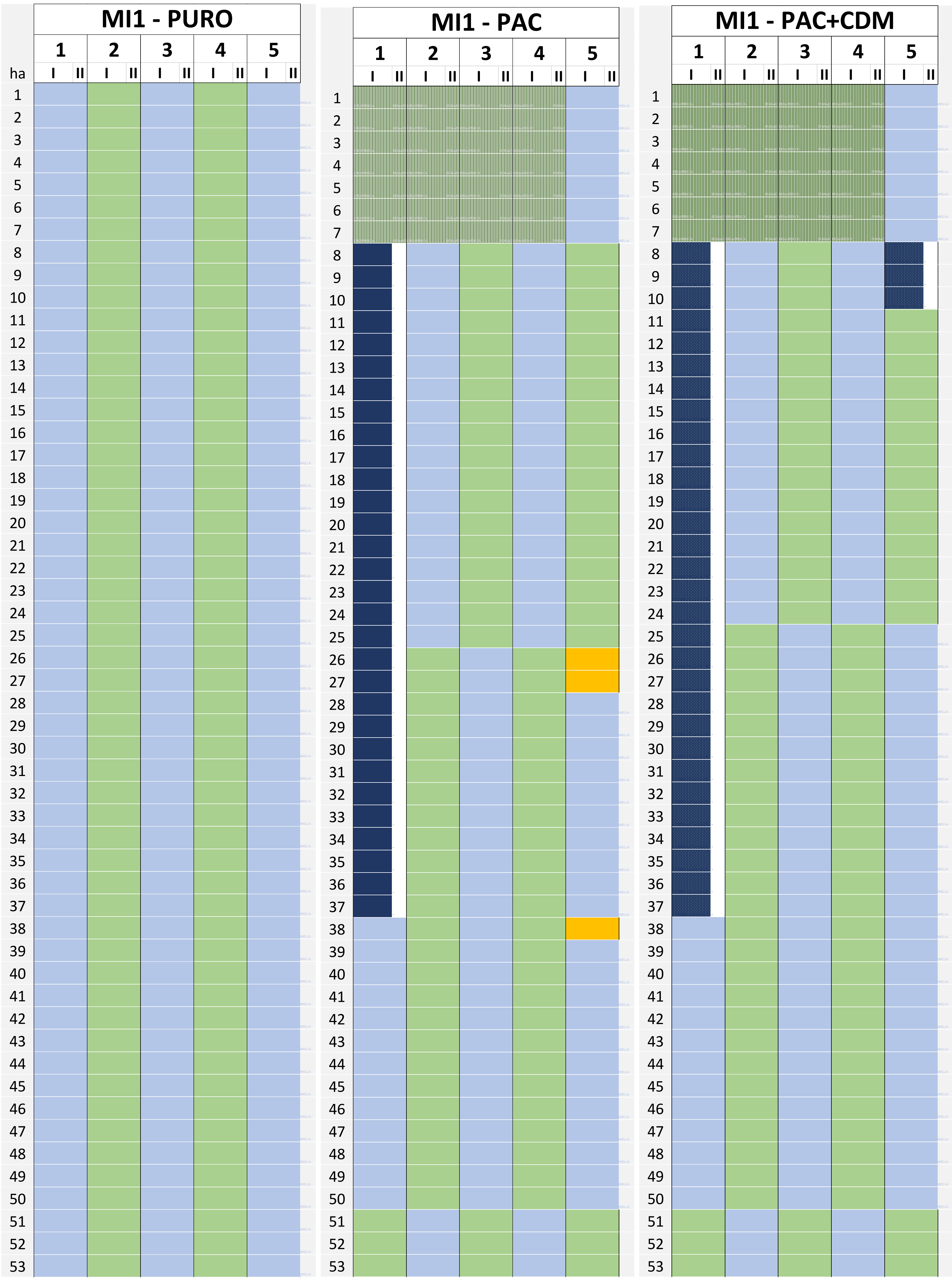
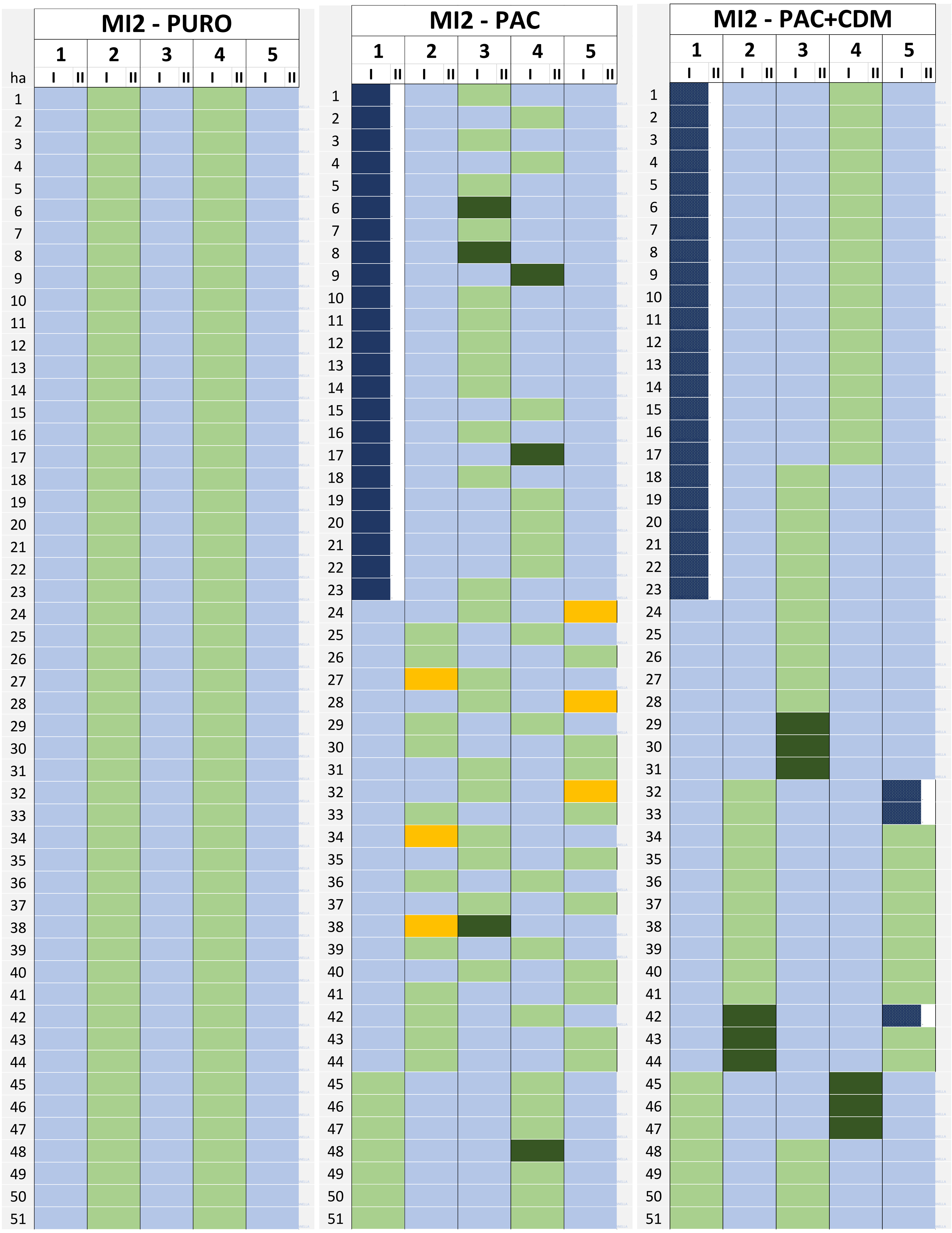


*Figure 18 – **MI2** UAA graphic rendering for the three considered scenarios*



Lombardia - MI1

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of corn and pea. This is linked to the high-income of those two crops. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. The introduction of alfalfa in the first year have a repercussion for the following three years (13% of UAA). The private initiative action is linked to UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverishing-renewal-improvement crops.

Lombardia - MI2

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of corn and pea. This is linked to the high-income of those two crops. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. In terms of crop diversification in the five years there isn't a substantial change: the most cultivated crops are corn and pea. The private initiative action is linked to UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverishing-renewal-improvement crops.

*Figure 19 – **MN1** UAA graphic rendering for the three considered scenarios*

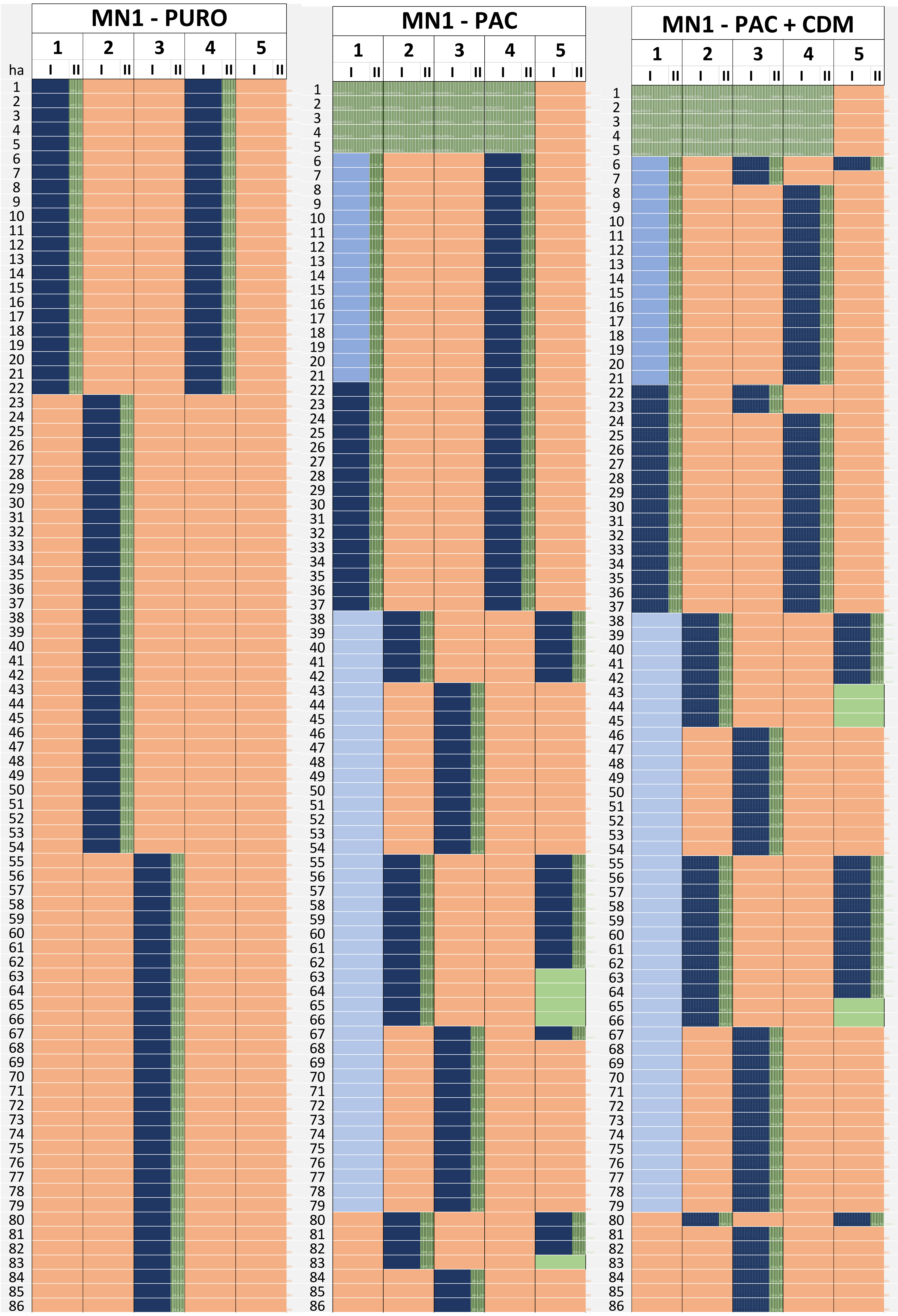
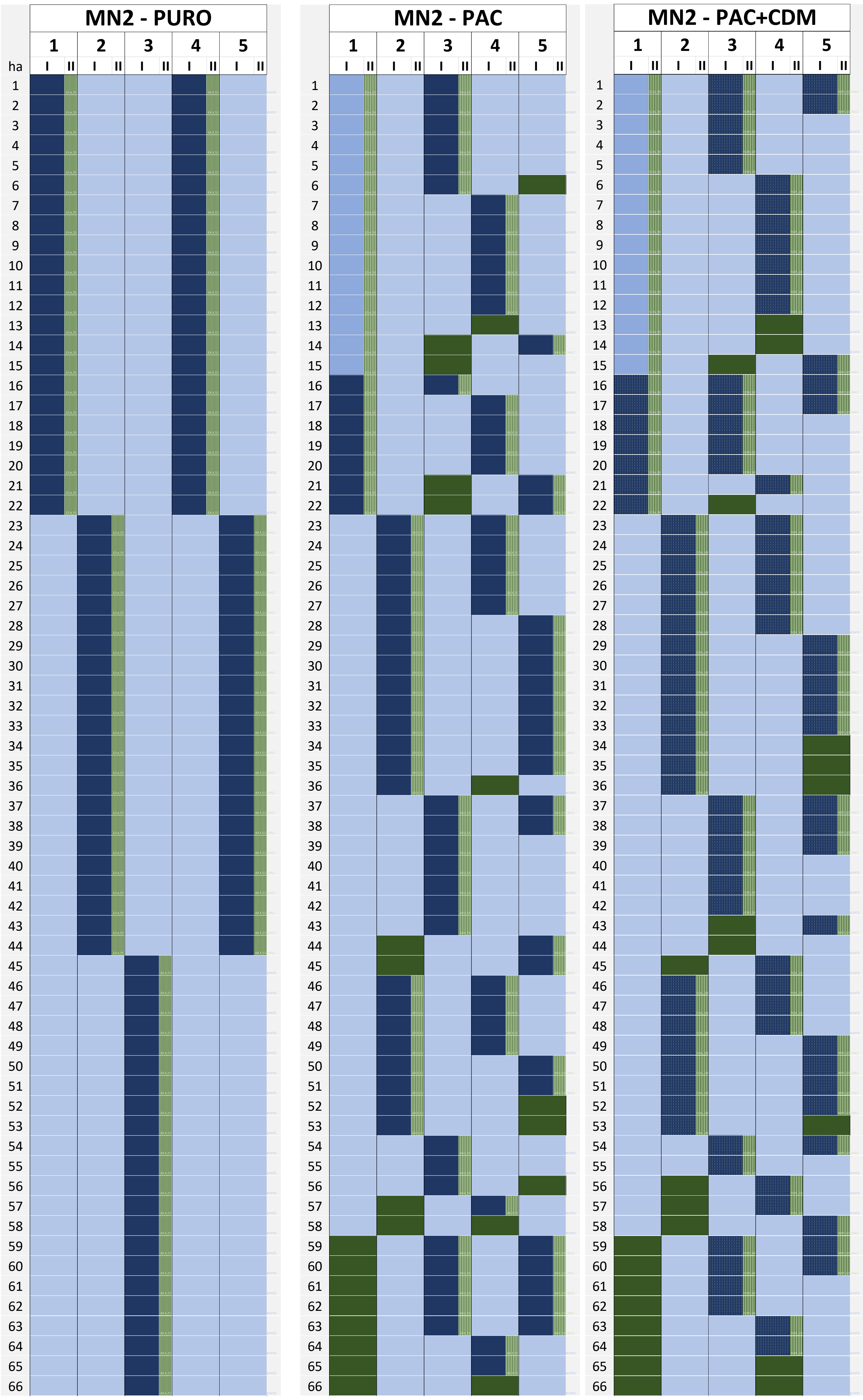


*Figure 20 – **MN2** UAA graphic rendering for the three considered scenarios*



Lombardia - MN1

The Pure farmer scenario shows a scenario characterized by the high presence of tomato in the five years: more than 60 % of UAA. We find a minimum of crop rotation based on the succession of tomato with soft wheat and second harvest soy. However, there is a tomato mono-succession for two or three years. This is linked to the high-income of this crop. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. We always find a high presence of tomato (30% of UAA as minimum from the second year), but in succession with soy and soft wheat. The introduction of alfalfa in the first year have a repercussion for the following three years. So, whit the CAP constrains we find a more virtuous land use characterized by a crop rotation based on the succession of renewal crop and improver crop. The second harvest soy play a fundamental role in a virtuous crop rotation planning: for every cereal hectare we have the following cultivation of this second harvest grain legume. However, there is a tomato mono-succession for two years.

Lombardia - MN2

The Pure farmer scenario shows a scenario characterized by the high presence of corn in the five years: 67 % of UAA. We find a minimum of crop rotation based on the succession of corn with soft wheat and second harvest soy. However, there is a tomato mono-succession for two years. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. In addition to these we have introduction of first harvest soy (grain legumes) only to comply to the CAP greening constrains (5% of UAA). The second harvest soy play a fundamental role in a virtuous crop rotation planning: for every cereal hectare we have the following cultivation of this second harvest grain legume. However, there is a corn mono-succession for two years in some plots.

*Figure 21 – **MN3** UAA graphic rendering for the three considered scenarios*

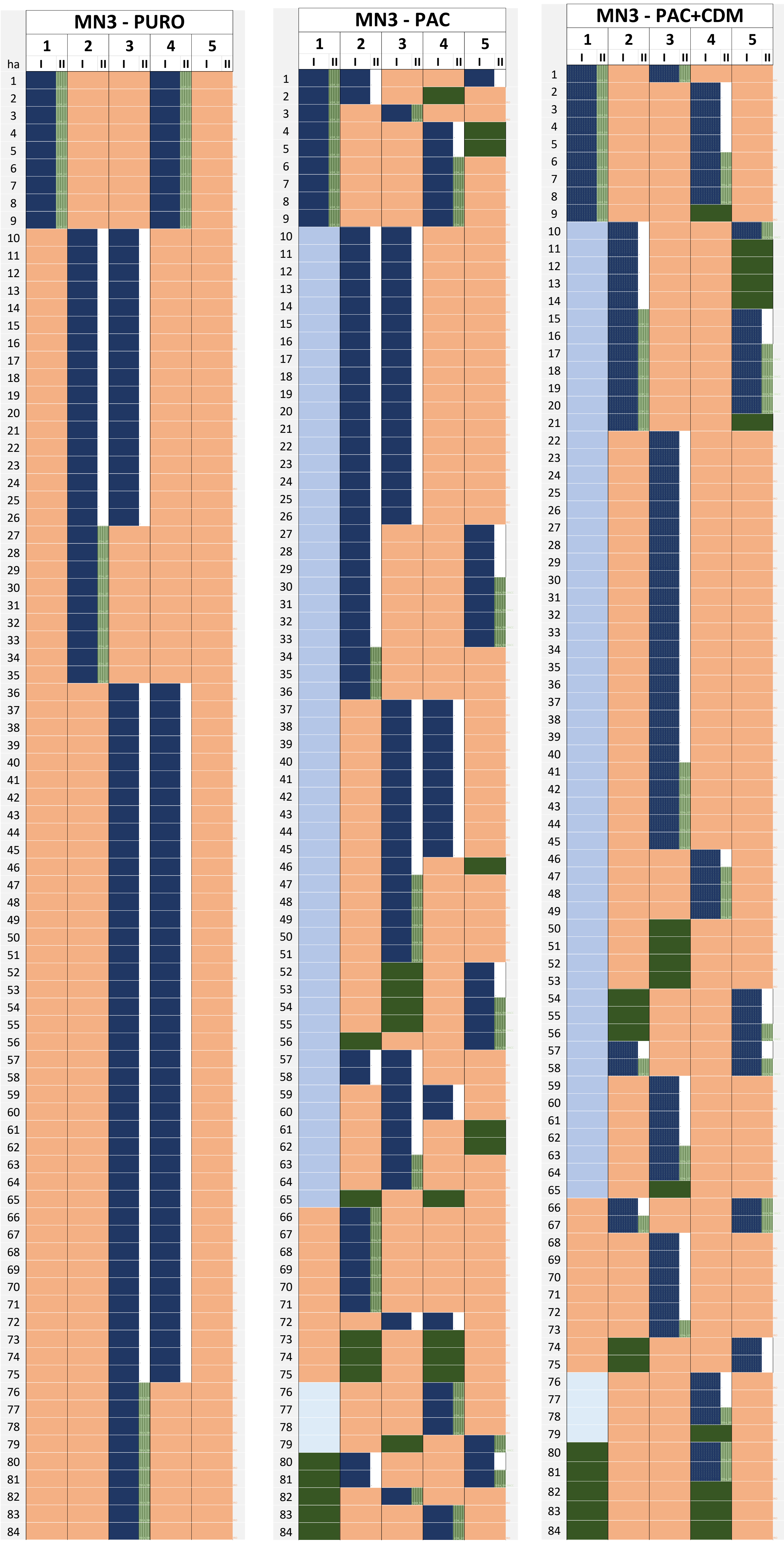
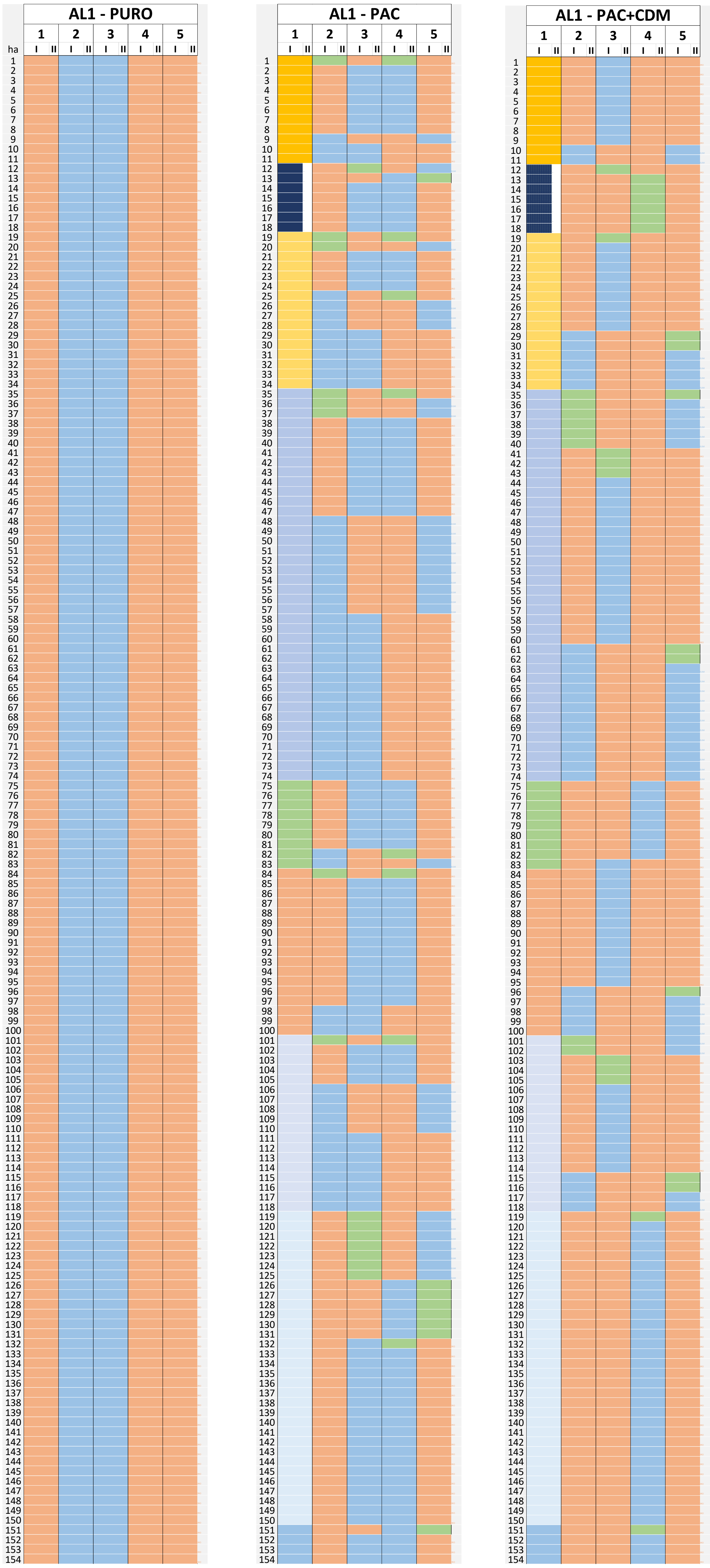


*Figure 22 – **AL1** UAA graphic rendering for the three considered scenarios*



Lombardia - MN3

The Pure farmer scenario shows a scenario characterized by the high presence of tomato in the five years: more than 60 % of UAA. We find a of crop rotation based on the succession of tomato with soft wheat and second harvest soy. However, there is a tomato mono-succession for two or three years. This is linked to the high-income of this crop. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. We always find a high presence of tomato (40% of UAA as minimum from the second year), but in succession with soy and soft wheat. The introduction of alfalfa in the first year have a repercussion for the following three years. So, whit the CAP constrains we find a more virtuous land use characterized by a crop rotation based on the succession of renewal crop and improver crop. The second harvest soy play a fundamental role in a virtuous crop rotation planning: for every cereal hectare we have the following cultivation of this second harvest grain legume. However, there is a tomato mono-succession for two years.

Piemonte - AL1

The Pure farmer scenario shows a monoculture result. In all the years the farm's UAA is dedicated to one crop and the most high-income crops: first year tomato; tritordeum for the following two years and two years of tomato. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as the greening constrains rule say. So, we find a high presence of tomato linked to the CAP coupled payments (more than 25 % starting from the second year) and a crop rotation based on succession of renewal and impoverishing crops (tritordeum; tomato). However, there is a tomato mono-succession for two years. The grain legumes introduction is only linked to comply the greening constrains (5% of UAA). The private initiative action is linked to UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverishing-renewal-improvement crops. However, there is a tomato mono-succession for two years.

*Figure 23 – **AL2** UAA graphic rendering for the three considered scenarios*

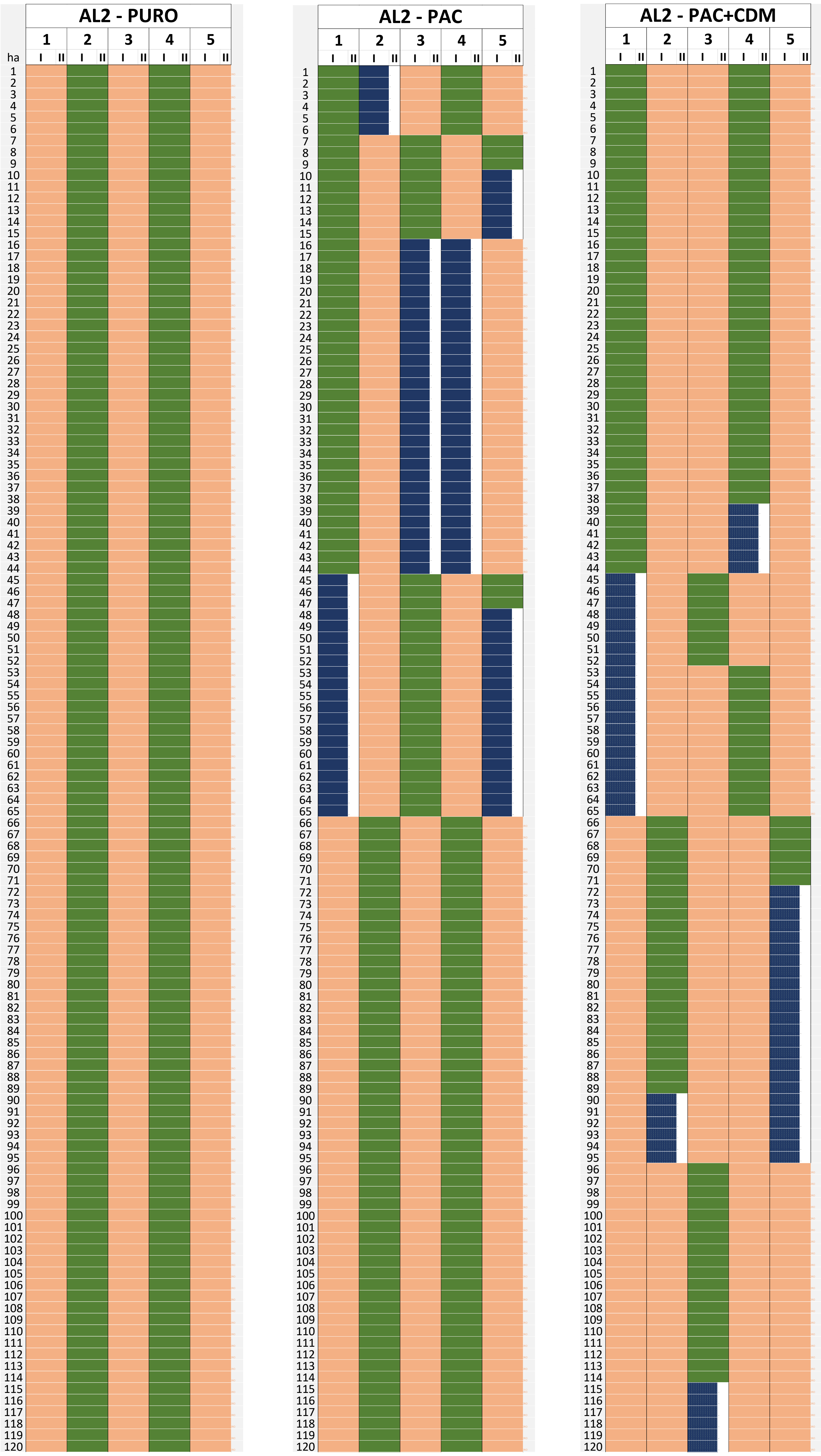
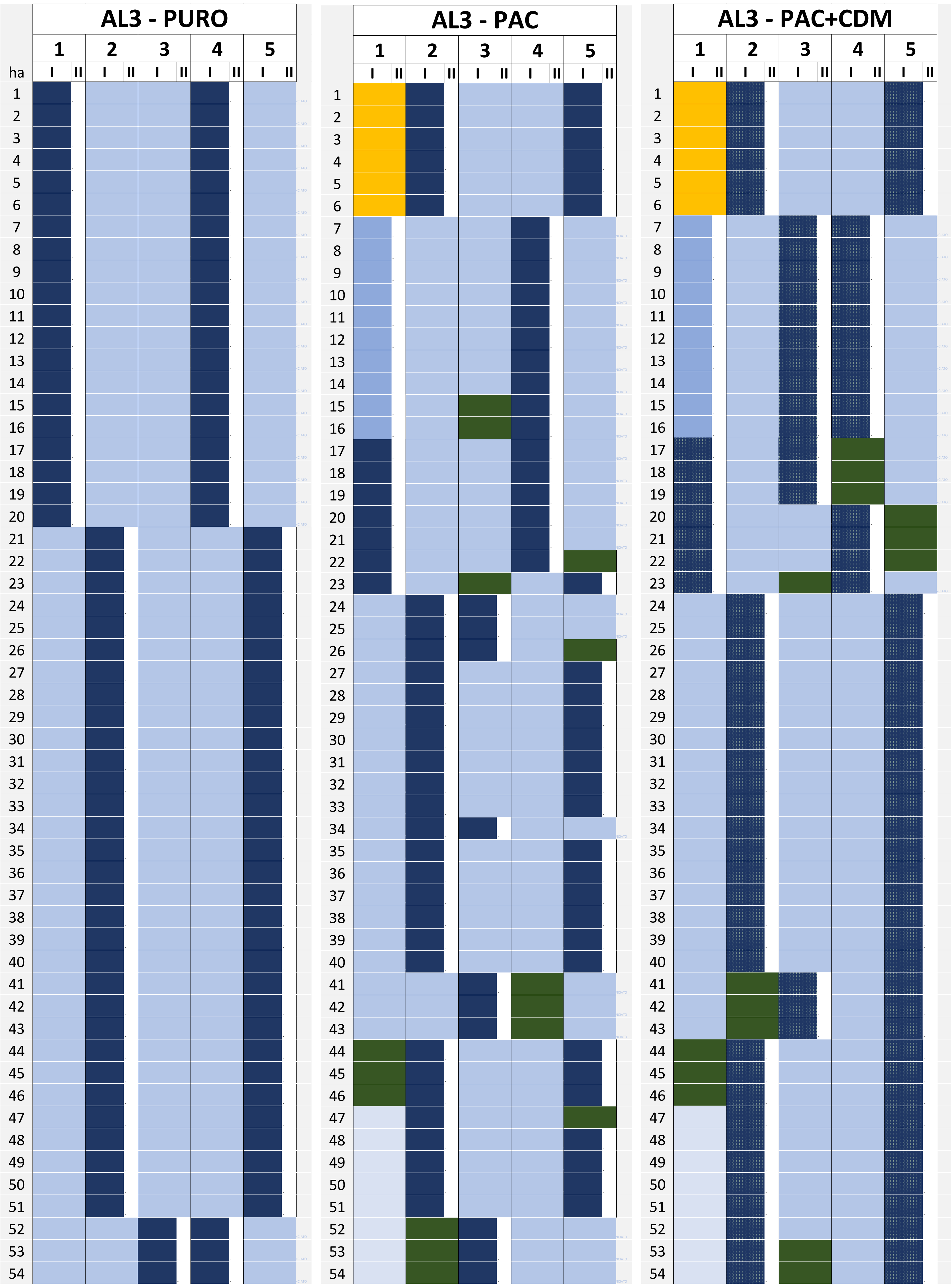


*Figure 24 – **AL3** UAA graphic rendering for the three considered scenarios*



Piemonte - AL2

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of tomato and chickpea. This is linked to the high-income of those two crops. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. We have the introduction of soft wheat cultivation in crop rotation with chickpea and tomato. The private initiative action has an important influence in the crop rotation plan. We find Cdm Soft wheat cultivation for all the five years. This is a great result in terms of crop diversification linked to the 3% of soft wheat UAA dedicate to flower strips. So, we can observe a good crop rotation based on the succession of impoverishing, renewal, and improver crop.

Piemonte - AL3

The Pure farmer scenario shows a scenario characterized by the presence of cereals in five years. However, through the years we can observe a crop rotation based on the alternation of corn and soft wheat. This is linked to the high-income of this crop. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. We always find a high presence of cereals (95% of UAA dedicate to soft wheat and corn). The grain legumes introduction is only linked to comply the greening constrains (5% of UAA). The private initiative action has an important influence in the crop rotation plan. We find Cdm Soft wheat cultivation for all the five years. This is a great result in terms of crop diversification linked to the 3% of soft wheat UAA dedicate to flower strips. So, we can observe a good crop rotation based on the succession of impoverishing, renewal, and improver crop.

*Figure 25 – **AL4** UAA graphic rendering for the three considered scenarios*

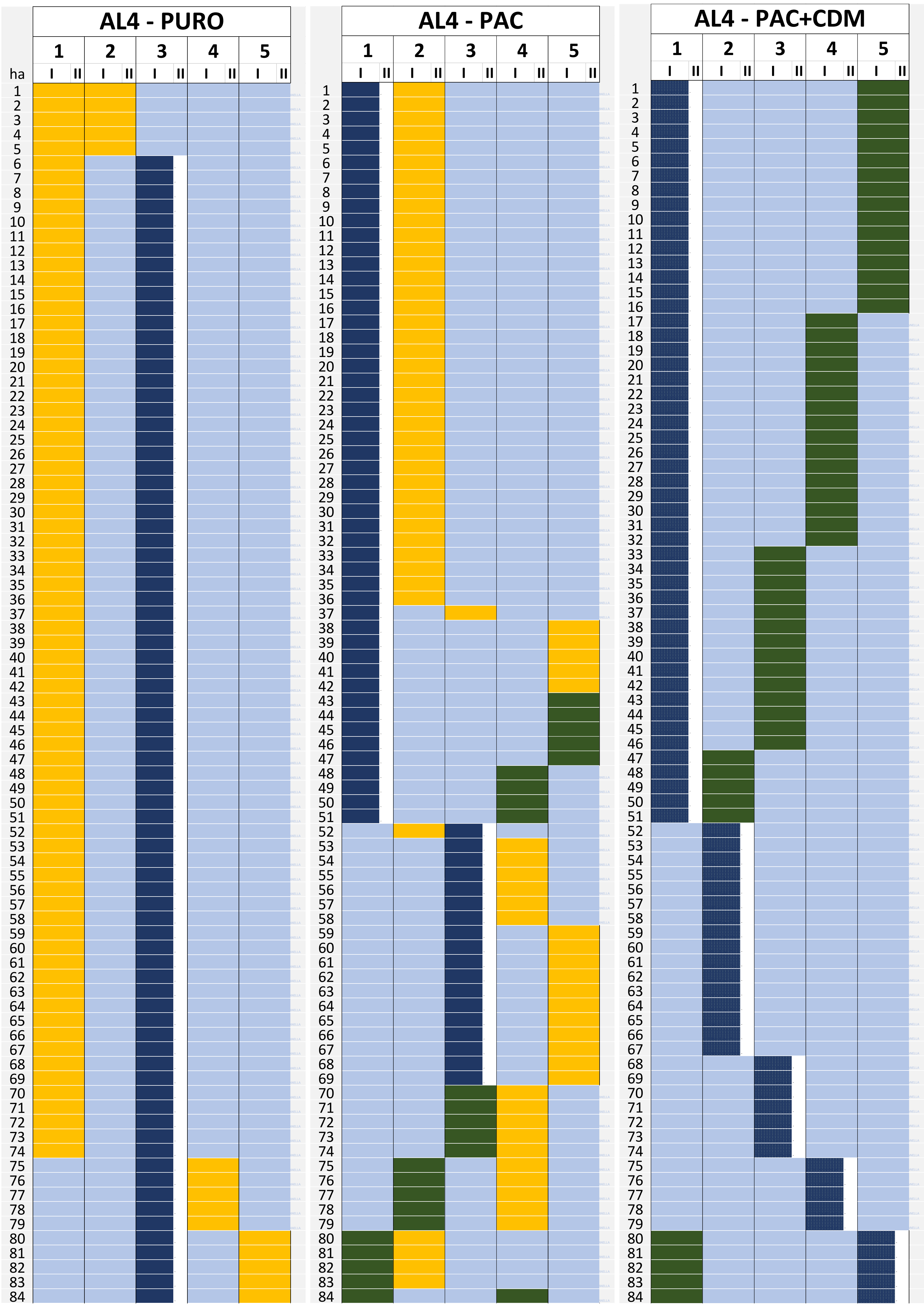
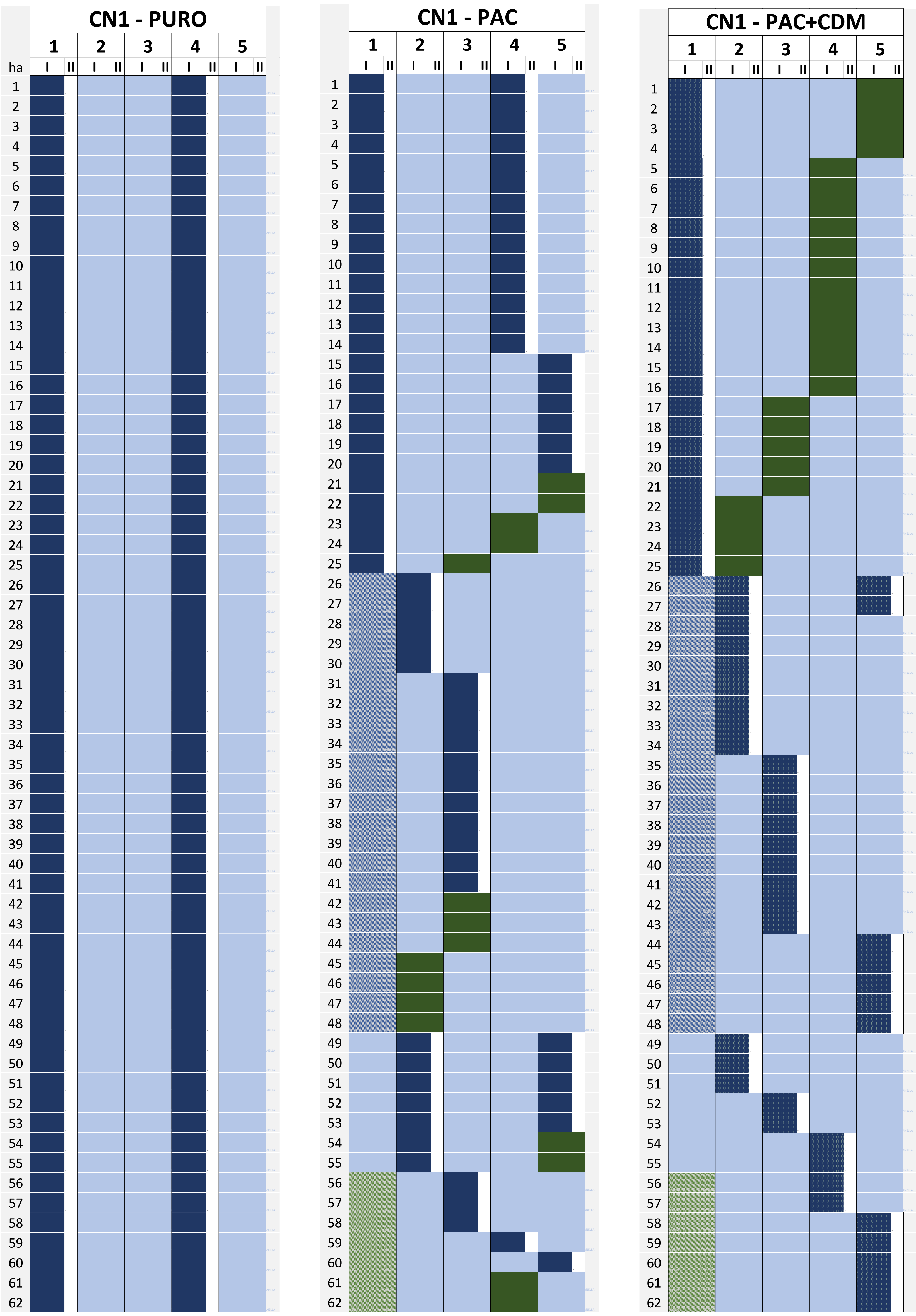


Figure 26 – ***CN1*** *UAA graphic rendering for the three considered scenarios*



Piemonte - AL4

The Pure farmer scenario shows a scenario characterized by the high presence of cereals in five years and by the cultivation of rapeseed. So, we have a presence of two crops in the year and a crop rotation trough the years based on the succession of two renewal crops (rapeseed; corn) and an impoverishing crop (soft wheat). However, there is a corn mono-succession for two and three years. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. There is always a corn mono-succession for two and three years. The private initiative action has an important influence in the crop rotation plan. We find Cdm Soft wheat cultivation for all the five years. This is a great result in terms of crop diversification linked to the 3% of soft wheat UAA dedicate to flower strips. In addition to this the private initiative crop rotation constrains enhance the cultivation of grain legumes starting from the third year: 17% of UAA . So, we can observe a good crop rotation based on the succession of impoverishing, renewal, and improver crop.

Piemonte - CN1

The Pure farmer scenario shows a monoculture result. In all the years the farm's UAA is dedicated to one crop and the most high-income crops: soft wheat and corn. In addition to this we have is a corn mono-succession for two years. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. There is always a corn mono-succession for two and three years. The grain legumes introduction is only linked to comply the greening constrains (5% of UAA). The private initiative action has an influence in the crop rotation plan. We find Cdm Soft wheat cultivation for all the five years. This is a great result in terms of crop diversification linked to the 3% of soft wheat UAA dedicate to flower strips. In addition to this the private initiative crop rotation constrains enhance the cultivation of grain legumes for the fourth year: 19% of UAA. So, we can observe a good crop rotation based on the succession of impoverishing, renewal, and improver crop. There is always a corn mono-succession for two and three years.

*Figure 27 – **CN2** UAA graphic rendering for the three considered scenarios*

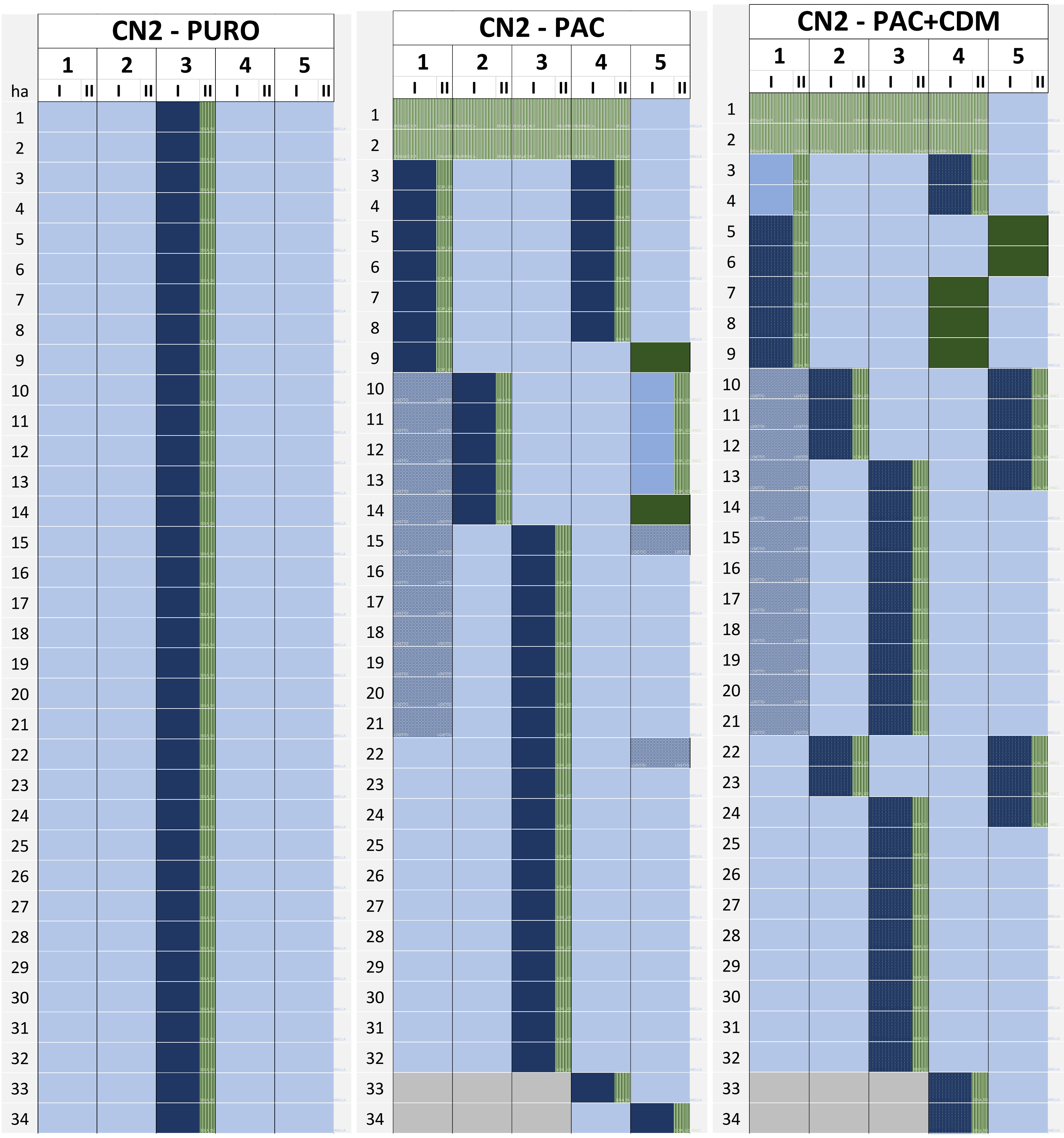
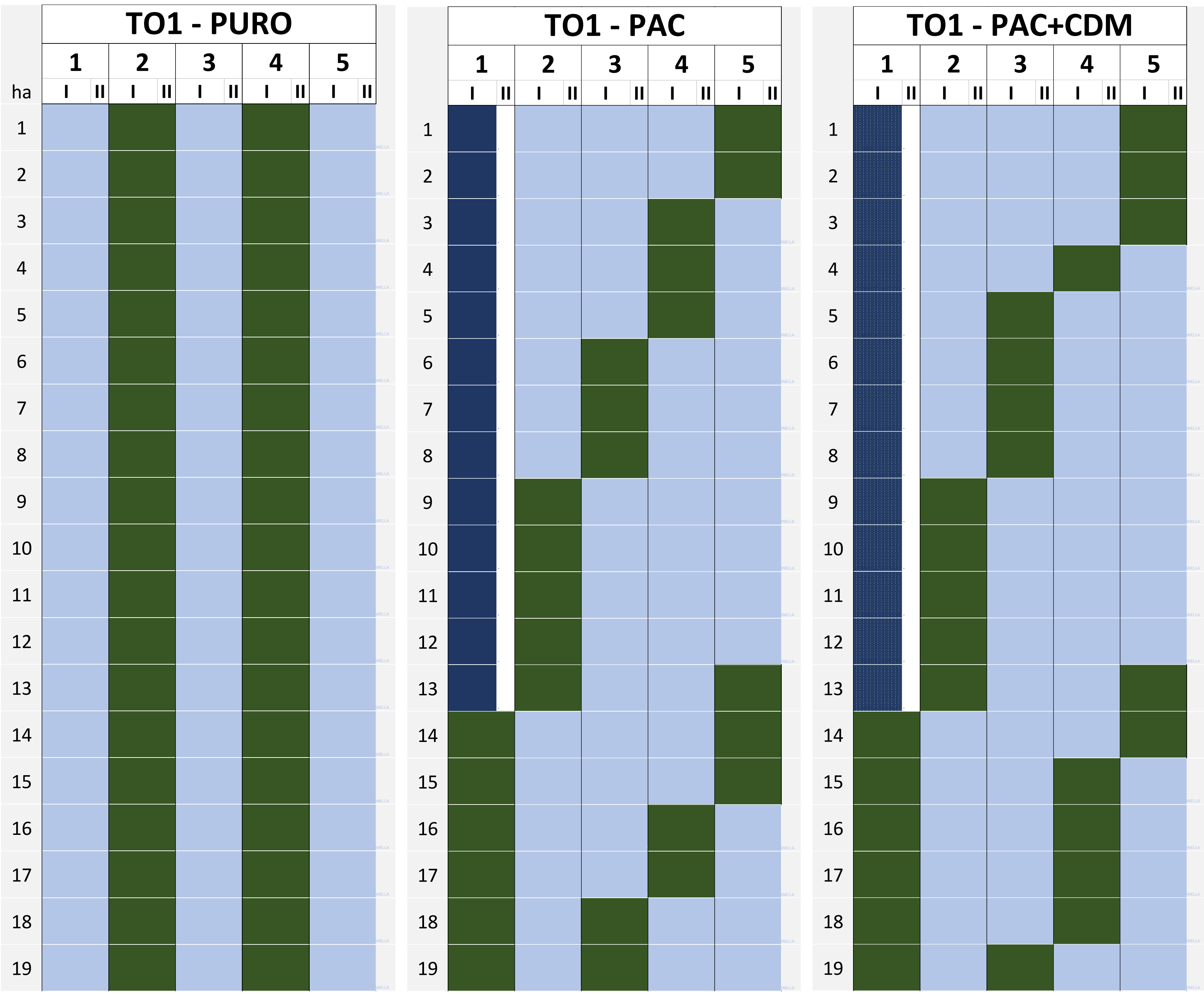


*Figure 28 – **TO1** UAA graphic rendering for the three considered scenarios*



Piemonte - CN2

The Pure farmer scenario shows a monoculture result. In all the years the farm's UAA is dedicated to one crop and the most high-income crops: soft wheat and corn. However, the farm's possibility to grow soy as a second harvest crop can have an improver crop in 5 years, but we have a corn mono-succession for two years. The CAP scenario is characterized by the introduction of crop diversification within the years: 4 crops as minimum, more as the greening constrains rule say. We always find a high presence of cereals (corn and soft wheat), but in succession with second harvest soy. The second harvest soy play a fundamental role in a virtuous crop rotation planning: for every cereal hectare we have the following cultivation of this second harvest grain legume. However, there is a corn mono-succession for two years. The introduction of alfalfa in the first year have a repercussion for the following three years. So, whit the CAP constrains we find a more virtuous land use characterized by a crop rotation based on the succession of renewal crop and improver crop. The private initiative action has an important influence in the crop rotation plan. We find Cdm Soft wheat cultivation for all the five years. This is a great result in terms of crop diversification linked to the 3% of soft wheat UAA dedicate to flower strips. In addition to this the private initiative crop rotation constrains enhance the cultivation of grain legumes whit the cultivation of second harvest soy after soft wheat. So, we can observe a good crop rotation based on the succession of impoverishing, renewal, and improver crop.

Piemonte - TO1

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of corn and soy. This is linked to the high-income of those two crops. The CAP scenario is characterized by the introduction of crop diversification within the years. We always find a high presence of corn (74% of UAA), but in succession with soy (26% of UAA). The private initiative action is linked only in the UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverished-renewal-improvement crops.

*Figure 29 – **RO1** UAA graphic rendering for the three considered scenarios*

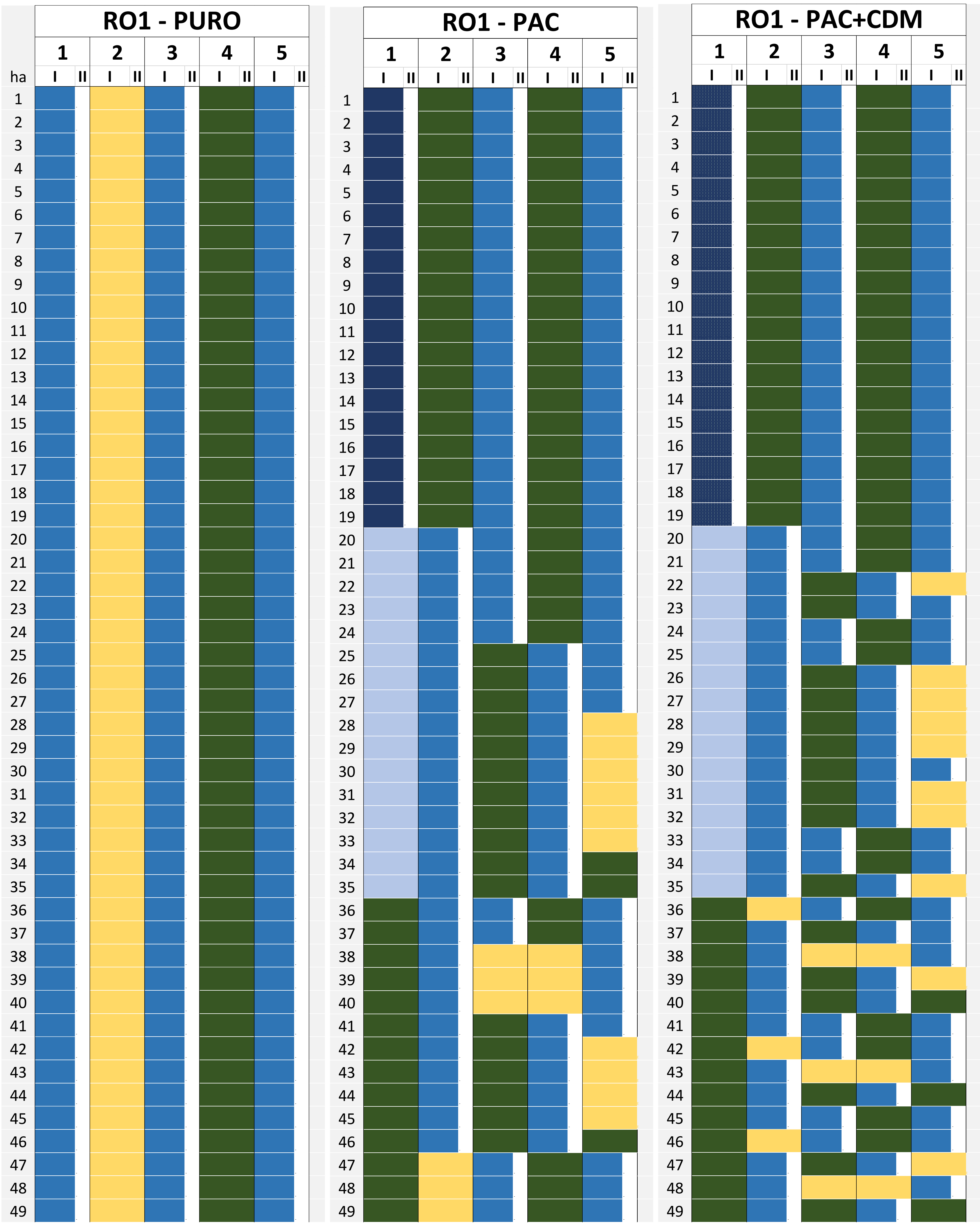
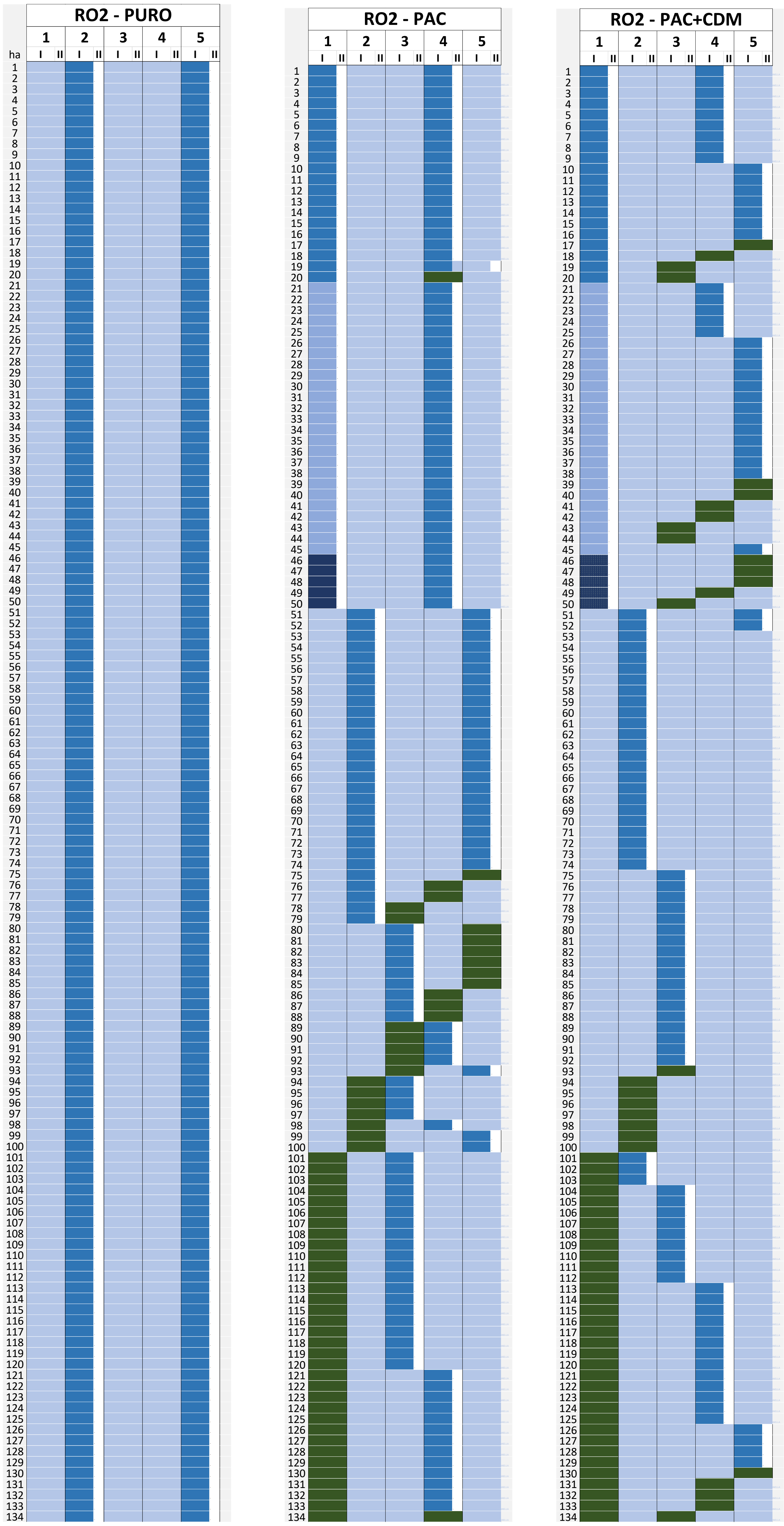


*Figure 30 – **RO2** UAA graphic rendering for the three considered scenarios*



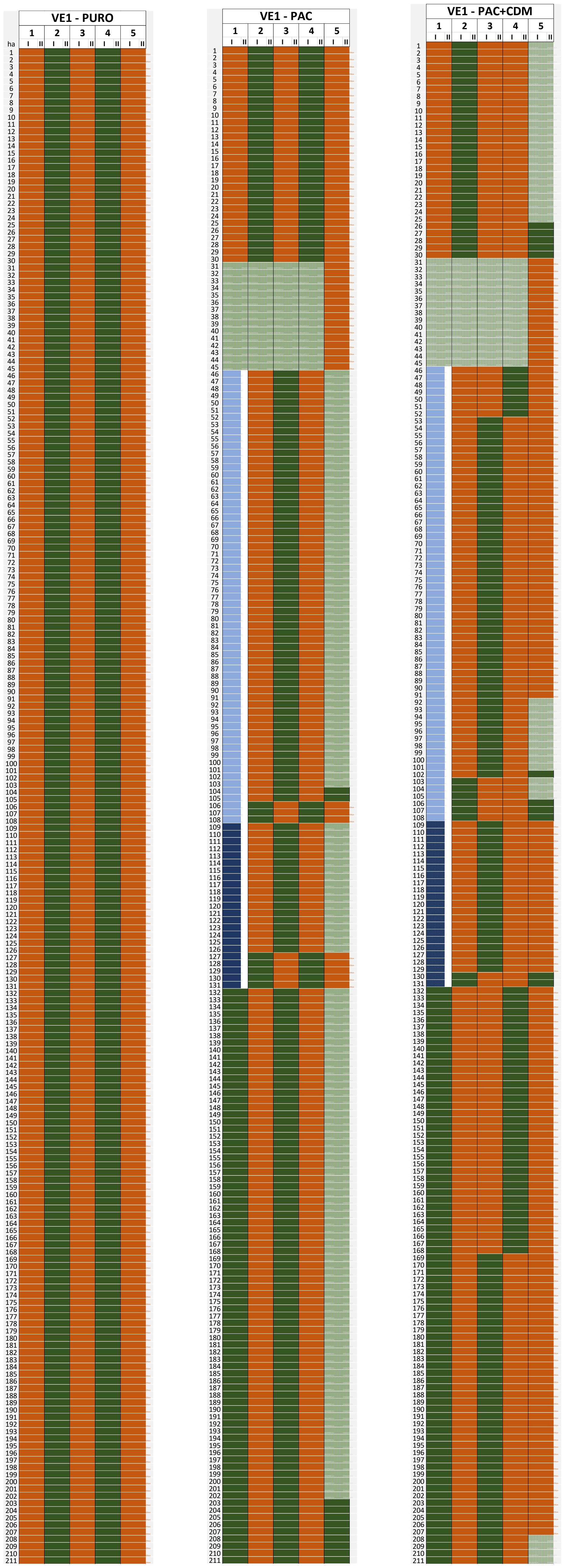
Veneto - RO1

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of durum wheat sunflower and soy. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum, as the greening constrains rule say. We always find a high presence of cereals (durum wheat), but in succession with soy and sunflower. So, whit the CAP constrains we find a more virtuous land use characterized by a crop rotation based on the succession of renewal improver and impoverishing crops. The private initiative action is linked only in the UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverished-renewal-improvement crops.

Veneto - RO2

The Pure farmer scenario shows a monoculture result. In all the years the farm's UAA is dedicated to one crop and the most high-income crops: soft wheat and corn. In addition to this we have is a corn mono-succession for two years. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. There is always a corn mono-succession for two years. The grain legumes introduction is only linked to comply the greening constrains (5% of UAA). The private initiative action is linked only in the UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverished-renewal-improvement crops.

*Figure 31 – **VE1** UAA graphic rendering for the three considered scenarios*



Veneto - VE1

The Pure farmer scenario shows a monoculture result. However, through the years we can observe a virtuous crop rotation based on the alternation of sugar beet and soy. This is linked to the high-income of those two crops. The CAP scenario is characterized by the introduction of crop diversification within the years: 3 crops as minimum as the greening constrains rule say. We have the introduction of alfalfa cultivation for five years. The private initiative action has an important influence in the crop rotation plan. The private initiative action is linked only in the UAA that start whit Cdm Soft Wheat (PAC+CDM scenario). In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverished-renewal-improvement crops.

The following table resume all the data that whit the graphic renderings developed and previous showed.

Table 16 - Resume of qualitative results for every scenario proposed.

Reg.	Farm	Pure	CAP	CAP+CDM
Emilia Romagna	BO1	monoculture	+ crop diversification + industrial crop + nitr. Fixers crops more than 5%	+ flower strips 1st year
	BO2	monoculture	+ industrial crop + nitr. fixer crops	+ flower strips 5 years + grain legumes 5 years
	BO3	monoculture grain nitr. fixer crops 2 years	+ crop diversification + industrial crop + grain nitr. fixer crops more than 5%	+ flower strips 5 years
	FE1	monoculture grain nitr. fixer crops 2 years	+ crop diversification + industrial crop - grain nitr. fixer crops	+ flower strips 1st year + grain nitr. fixer crops 1 year
	FE2	Monoculture grain nitr. fixer crops 2 years	+ crop diversification	+ flower strips 5 years
	FE3	Monoculture grain nitr. fixer crops 2 years	+ crop diversification	+ flower strips 5 years
	FE4	grain nitr. fixer crops 4 years	= crop diversification	
	PR1	industrial crop cereal	+ crop diversification + nitr. Fixers crops more than 5%	+ flower strips 2 years
Lombardia	MI1	monoculture; grain nitr. fixer crops 2 years	+ crop diversification	+ flower strips 1st year
	MI2	monoculture; grain nitr. fixer crops 2 years	+ crop diversification	+ flower strips 1st year

	MN1	industrial crop; cereal; second harvest soy	+ crop diversification + grain nitr. fixer crops more than 5%	
	MN2	cereal; second harvest soy	+ crop diversification	
	MN3	industrial crop; cereal; second harvest soy	+ crop diversification + grain nitr. fixer crops	
Piemonte	AL1	monoculture	+ industrial crop + grain nitr. fixer crops	+ flower strips 1st year
	AL2	monoculture grain nitr. fixer crops 2 years	+ crop diversification	+ flower strips 5 years
	AL3	cereals	+ crop diversification + grain nitr. fixer crops	+ flower strips 5 years
	AL4	cereals; oil crops	+ crop diversification + grain nitr. fixer crops	+ flower strips 5 years + grain nitr. fixer crops 5 years
	CN1	monoculture; cereals	+ crop diversification + grain nitr. fixer crops	+ flower strips 5 years + grain nitr. fixer crops 1 year
	CN2	monoculture; cereal; second harvest soy	+ crop diversification + grain nitr. fixer crops more than 5%	+ flower strips 5 years + grain nitr. fixer crops 5 years
	TO1	monoculture grain nitr. fixer crops 2 years	+ crop diversification + grain nitr. fixer crops more than 5%	+ flower strips 1st year
Veneto	RO1	Monoculture grain nitr. fixer crops 1 year	+ crop diversification + grain nitr. fixer crops more than 5%	+ flower strips 1st year
	RO2	Monoculture cereals	+ crop diversification + grain nitr. fixer crops	+ flower strips 1st year
	VE1	monoculture	+ crop diversification	+ flower strips 1st year

If we look at those results the elaboration can show differences between farms, but we can resume the following actions in qualitative differentiation of arable land use of those high specialized farms. In most of farms the reconstructed condition of “Pure farmer” shows a monoculture arable land use for the single year. However, through the years we can observe a crop rotation based on the succession of different crops. In 12 farms the pure condition considering the cultivation of a nitrogen-fixer crop. Those farms are mainly located in provinces where grain legumes and forages are in the ordinary arable land use. The greening CAP constrains actions improve the crop diversifications in all farms through the years. In seven farms the CAP action improves the nitrogen fixers crop cultivation in more than the 5% minimum required by greening. This result confirm that we have seen previously whit quantitative results: the convergence between greening payments (CapG) and coupled payments (CapC) it ‘is an important lever to enhance the virtuous crop rotation (soy - CapC). At the same time the coupled payments improve the cultivation of industrial crops (sugar beet – tomato) and that can be a constrain in a prevision of a good crop rotation, because we find in some farms mono-succession for two or three years.

The introduction in the first year of crop rotation of the case study private initiative have different actions related to the CAP scenario. In 9 farms we can observe the CdM soft wheat cultivation only for the first year. In these, more than 3% dedicated to flowering strips, there is a crop rotation that provides for the alternation of impoverished-renewal-improvement crops. In 9 farms we can observe the CdM soft wheat cultivation only for all the five years of crop rotation, and in 5 of those the private initiative crop rotation rule enhances the nitrogen-fixers crop cultivation for all the five years. So, we can observe two level of outputs in terms of agroecology values: 1- crop diversification promoted by the introduction of flower strips. 2 – more virtuous crop rotation promoted by the introduction of nitrogen fixers crops.

CONCLUSIONS AND FUTURE PERSPECTIVES

Over the years of research, we have realized that answering the questions posed in the initial phase was very ambitious. The bibliographic and methodological research carried out has however allowed us to arrive at results which have demonstrated the value of the work carried out.

The literature analysed during the first part of the research made it possible to identify the actors involved in the agroecological transition of the agricultural sector and their current position with respect to it (Figure 32).

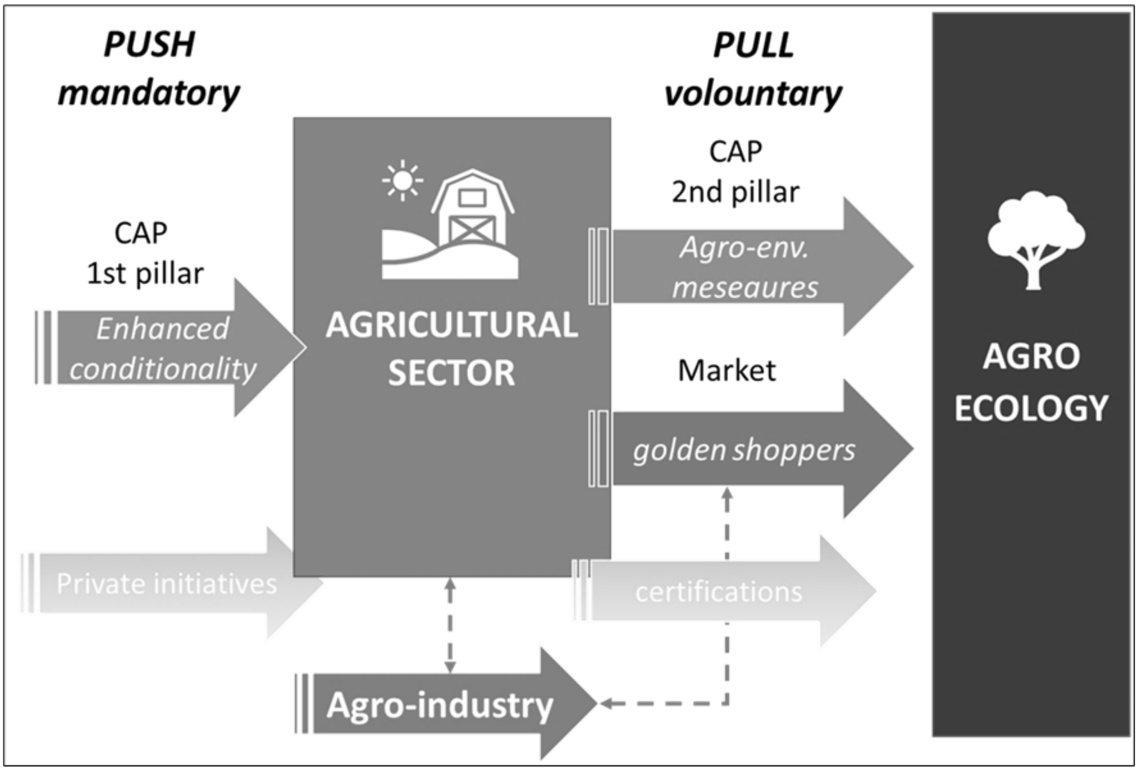


Figure 32 - Transition of the agricultural sector to the agroecology. (Source: own elaboration)

The literature review on the impacts of some agroecological practices on income and productivity at farm level does not show clear stability of the economic impacts. In this context, the analysis of the literature carried out by Julia Rosa-Schleich shows different economic benefits at farm level (Rosa-Schleich *et al.*, 2019). However, these are based in part on meta-analyses and in part on case studies coming from different countries, productive contexts, and socio-cultural contexts. This general view is confirmed by other literature references analysed. Altieri and Toledo (2011) provides an overview of what they call ‘agroecological revolution’ whit a case study located in Latin America (Altieri and Toledo, 2011). In the same wake Dogliotti et al. (2013) show the economic results coming from a case study of 14 family farms located in southern Uruguay (Dogliotti *et al.*, 2013). Although the target of farmers is defined in a context of small-scale agriculture, a growing attention to these new models by companies and supply chains oriented to agro-industrial production. Different is the approach proposed by Lechenet et al. (2014) which aims to illustrate the differences between 48 farms located in regions of intensive arable farming in France in three different scenarios: conventional; integrated; organic (Lechenet *et al.*, 2014).

Following the Lechenet approach the thesis aim to evaluate the economic impact of different actions that promoting the agro-ecological transition for agricultural sector composed by farms specialized in arable land management for commodities production.

Over the years, the CAP policy has shown an approach based more and more on agroecological principles. The existing instruments of the 1st Pillar, based on enhanced conditionality and greening, have a very important value in terms of promoting pro-agro-ecological practices at farm level. But also, the 2nd pillar pulls with voluntary actions the agricultural sector to diversify their production methods in different ways.

In the last years, the agro-industry promote new approaches to the supply of raw materials. A first approach is based on buying certified raw materials. But certification schemes can have very diverse objectives, which can be described as the improvement of food safety by guaranteeing compliance with minimum standards and differentiating food products. With the aim of differentiating the product, different types of certifications insist on the market that looks at environmental and social issues oriented towards the sustainability. Some standards incorporate them, others are totally dedicated. The research conducted shows that only few of the most used certification schemes have correspondence to the main themes of agro-ecology proposed by FAO. Recently agro-industries have promoted others approaches based on private sustainable supply chain initiatives, and they have started communicating sustainability-claim related information about food to consumers, introducing labels and logos in-store and on-pack (Matopoulos et al., 2001; Blasi, Ruini and Monotti, 2017).

So, with this work it was possible to evaluate the impact of public policies and private initiative to which almost all farms adhere in the current production context of the Po Valley. The possibility of using real farms data made it possible to give value to the work carried out and at the same time to develop a specific evaluation methodology for the case study. The precious collaboration with the Department of Mathematical Sciences of the University of Siena has allowed the development of a model that has made possible answers to the research question posed both in quantitative and qualitative terms.

The economic results shows that CAP vector pull and push farmers to diversify their cropping systems by the greening rules. But is also important the convergence between greening payments (CapG) and coupled payments (CapC) resulted. In farms where we find crops with coupled payments subsidies, we find also the main strongness to comply whit greening rules, so to diversify cropping systems. The private initiative action goes to the same direction whit differences in action linked to crop rotation constrains that can affect the Gross Margin of the farms for five years. In most of the observed results the business tool promoted by Barilla can pull the farms to the agroecology approach considering five years of crop rotation. The qualitative results of the tool can confirm this direction of public policies and private initiative. Il all farms we can find a improve of crop diversification that led to a virtuous crop rotation based on agroecology principals.

So, the case study analysed made it possible to identify a synergistic action between public initiatives and private initiatives towards agro-ecology. Private actions therefore tend to strengthen the action to promote agroecological practices defined by current European policy. On the other hand, private initiatives must take into account the public policy instruments already adopted by farms in a specific farms production context.

In developing the research activities, it was possible to identify weaknesses of the experimental methodology adopted. It is right to take into consideration the fact that the proposed model provides an output based on the average of values found over the years. This data input certainly makes the results valid but does not take into consideration the fluctuation of the years in terms of yield and price. For this reason, as a future perspective, it is very important to modify the model that can take into account different scenarios based on the trend of agricultural years over the years.

Finally, the research carried out made it possible to identify the action of public policy and private initiative in the transition of the agricultural system towards agroecology. The case study showed positive results and made it possible to quantify the economic impact and crop diversification impact that farms have in different production schemes.

The model created can constitutes a basis for future development of a useful interface for farmers (web app). The methodology proposed can also be used by policy makers to estimate the economic impact of policy actions that promote a different approach to cultivation (CAP, RDPs).

Concluding, the thesis presented demonstrates that the agroindustry can push the agricultural sector to the agroecology, but only if supported by policy actions. The convergent action of private initiatives and public initiatives is the keystone in the complete adoption of the 10 elements of agroecology proposed by FAO.

ACKNOWLEDGMENTS

Every great effort requires the necessary help and therefore in this section I will try to thank all the people who have made it possible and who have contributed to the finalization of this path, both professionally and in life.

Ringrazio mia moglie Enrica, pilastro della vita, che ha saputo accompagnarmi con forza ed entusiasmo in questo percorso. Il secondo ringraziamento va al Professor Emanuele Blasi, per avermi accolto con fiducia e profonda amicizia, per avermi trasmesso il seme della ricerca e gli strumenti giusti per poterla affrontare, per essere stato il tutore della mia crescita professionale e per aver condiviso con me i frutti della ricerca effettuata. Debiti ringraziamenti vanno al Professor Paolo Detti ed al Dott. Mario Benini per le lunghe ore passate ad elaborare idee e dati, e per aver condiviso con me instancabilmente l’elaborazione del modello. Passo a ringraziare i compagni di viaggio la cui presenza si è resa essenziale durante gli anni. Il Dottore Agronomo Nicolò Passeri per la solidità bibliografica, il confronto, esperto e competente, non di meno per la consolidata amicizia; il ricercatore Angelo Martella per avermi trasmesso l’arte dell’elaborazione e della presentazione dei dati, per le iniziali lunghe sessioni informatiche e per la bellissima amicizia nata.

Ringrazio tutto il gruppo di lavoro Barilla che ha reso disponibili i propri dati ed ha dato fiducia nel progetto: Dott. Orlando Visciano, Dott. Michele Zerbini, Dott. Simone Agostinelli. Ringrazio il progetto H2020 DIVERFARMING (www.diverfarming.eu) che ha reso possibile questo mio periodo dottorale. Ringrazio tutte le aziende agricole ed i relativi tecnici tra Veneto, Emilia-Romagna, Lombardia e Piemonte per l’accoglienza ricevuta, la disponibilità e la professionalità con cui hanno aperto i loro cancelli.

Infine, un debito ringraziamento va a Brian Eno per aver scritto la perfetta colonna sonora per l’intero lavoro presentato.

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