Agroecological approach applied to Vercelli's rice farm to improve ecological and economic sustainability

POLITECNICO DI TORINO

Corso di Laurea Magistrale
in Design Sistemico

Tesi di Laurea Magistrale

"Agroecological approach applied to Vercelli's rice farm to improve ecological and economic sustainability"

Relatore:

prof. Elena Comino

Candidata

Elisa Magi

Anno Accademico 2020/2021

INDEX

LEGENDA

ECOSYSTEM SERVICES ICONS

Air quality regulation	Soil formation
Water regulation	Nutrient Cycling
Disease and pest regulation	Recreation and ecotourism
Water purification and waste treatment	Food
Aesthetic value	Habitat

SWOT AND STRATEGIES ICONS

Priorato farm characteristics	Rice
Cultivation and agroecological techniques	Ricreational and educational activities
Water management	Productivity
Emissions	Economical aspects
Chemical products	Biodiversity

STRATEGIES

SO Strengths + Opportunities	WO weaknesses + Opportunities
ST Strengths + Threats	WT weaknesses + Threats


Photo by Claudia Fernan on Unsplash

1.0 Introduction

Rice is one of the most important food crops and is the most widely consumed cereal by humans, with 50% of the world's population dependent on it.
The largest rice production is found in Asia, where for hundreds of millions of small farmers rice is the only source of income (Coltura & Cultura, n.d).
Data collected shows that in the world 155 million hectares of land are cultivated with rice (Fao, 2019) and in 2019, 487 million tons of rice were consumed in the world (Statista, 2020).
This production has an impact on air quality, as a matter of fact, one hectare cultivated with rice emits on average 3.52 kg of methane and 1.17 kg of nitrous oxide per year (Corinair methodology) (ARPA Veneto, 2017).
However, intensive rice production generates threats, that are not only related to methane and nitrous oxide emissions.
The entire ecosystem is threatened by the invasive techniques used in agriculture, which aim to maximise profits while damaging the environment.

Rice paddies, above all, give life to a very particular ecosystem. They are temporary wetlands, which means that the special conditions created in these environments by the continuous presence of water for short or long periods provide a perfect habitat for many species, thus enriching biodiversity.
Agricultural processes turn this ecosystem into an ecological trap in which many species cannot survive (Calhoun, et al., 2016) (Lawler, 2001) (Verhoeven & Setter, 2010).
However, biodiversity is an important factor to be taken into account as it can bring numerous benefits to agriculture. For example, it can naturally contain the development of diseases, pests and weeds, improve soil structure, soil fertility and nutrient cycling, and improve air quality (Calaciura, De Amicis, Gisotti, & Zaghi, 2012).

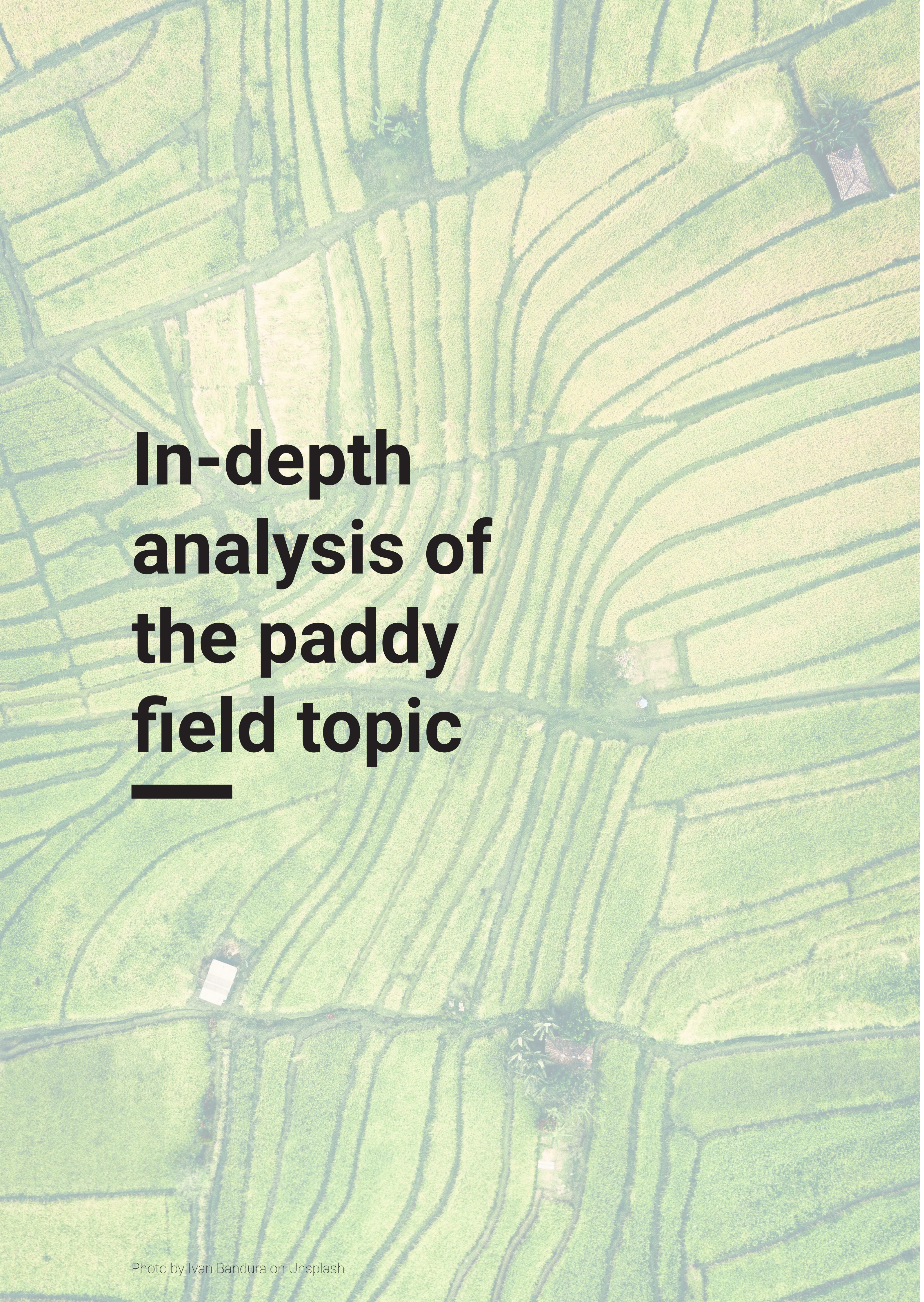
It is also important to look at the agricultural sector from a global perspective, considering certain aspects that need to be addressed as soon as possible in order to deal with future problems.
Indeed, one of the biggest challenges facing this sector is the increase in demand for food, which corresponds to a 70% increase in food production by 2050. It is estimated that cereal production will have to increase by about one billion tonnes and meat production by about 200 million tonnes.

To meet these needs, arable land would have to increase by about 120 million hectares, which is highly unlikely given the threat created by climate change (FAO, 2009).

One solution to the growing demand is to make better use of scarce natural resources.
For example, by integrating several crops into one field or by integrating livestock farming with some crops.
In this way, it is possible to obtain different products from a single space, trying to restore the natural ecosystem which is characterised by diversity, adaptability and resilience (Altieri, 2018) (Koohafkan, Altieri, & Holt Gimenez, 2012).

The aim of this thesis is to assess the feasibility of this type of agriculture, taking the Italian context as a reference, in particular the area of Vercelli where a farm was selected as a real case study.
After having assessed the numerous benefits of integrated agriculture, the data provided by the farm were used to evaluate the economic aspect.

In order to approach the topic in the best possible way, the thesis was divided into two parts.
The first part consists of an in-depth analysis of the rice ecosystem. Firstly, in chapter 2.0 the quantitative data concerning rice production in the world, in Italy and in the province of Vercelli were reported.
In the next chapter, the different types of rice paddies in the world are described, as well as the cultivation techniques used in Italy from the beginning of the 20th century to the present day. After describing the rice field from an agricultural point of view, it is also analysed from an ecological point of view, through the definition of ecosystem services.
Finally, the first block concludes with the SWOT analysis and the creation of strategies, and the construction of the ecological matrix.
The second block begins with chapter 4.0 in which the farm used as a case study is described in detail.
In the next chapter, the data gathered from a detailed analysis of the literature on integrated farming systems is presented, laying the foundations for the implementation of the new system, which is described in chapter 6.0.



In-depth analysis of the paddy field topic

Photo by Ivan Bandura on Unsplash

To introduce the topic concerning the rice ecosystem, data concerning the global context were first analysed. Therefore, data describing the world situation regarding production, consumption and emissions were collected. Then, in order to approach the area of interest, the Italian context was taken into consideration.
Data was collected on Italian rice production: the hectares of rice fields in Italy and how much rice they produce, the companies involved in rice production and the varieties cultivated.
The range of interest was then narrowed down to the most productive area in Italy, followed by a focus on data concerning the province of Vercelli.
Finally, the rice ecosystem was analysed, starting with a description of the various rice systems in the world and the cultivation systems used in Italy in the past and today, and ending with an analysis of ecosystem services.
At this point, to conclude the analysis of the rice agro-ecosystem, a SWOT and an ecological matrix were constructed.

Photo by Magdalena Love on Unsplash

2.0 Background data

First of all, to fully understand the topic, it is necessary to analyse some data. In the following sections are reported some information about the production, consumption, export of rice and emissions due to its production at global and Italian level, ending with a focus on data concerning the province of Vercelli (Piedmont Region, Italy).

2.1 Rice data in the world

#production

Rice is the most important food crop in the world, being by far the most widely used cereal for human consumption, the survival of more than 3 billion people depends on rice. The 50% of the world's population depends on rice for its nutrition for a lifetime (without forgetting that rice is the first cereal consumed during weaning) and some hundreds of millions of small farmers have rice as their main and sometimes only source of income. In Asia, more than two billion people get the 60/70% of their daily energy intake from rice and rice-based products. Around the 80 % of the world's rice is produced by smallholder farmers, and the most of it is consumed locally, although its international trade is increasing. Rice production in sub-Saharan Africa is also expanding more than other crops. In Latin America and the Caribbean, twenty-six countries cultivate rice, the 43% of world rice production (Coltura & Cultura, n.d.).

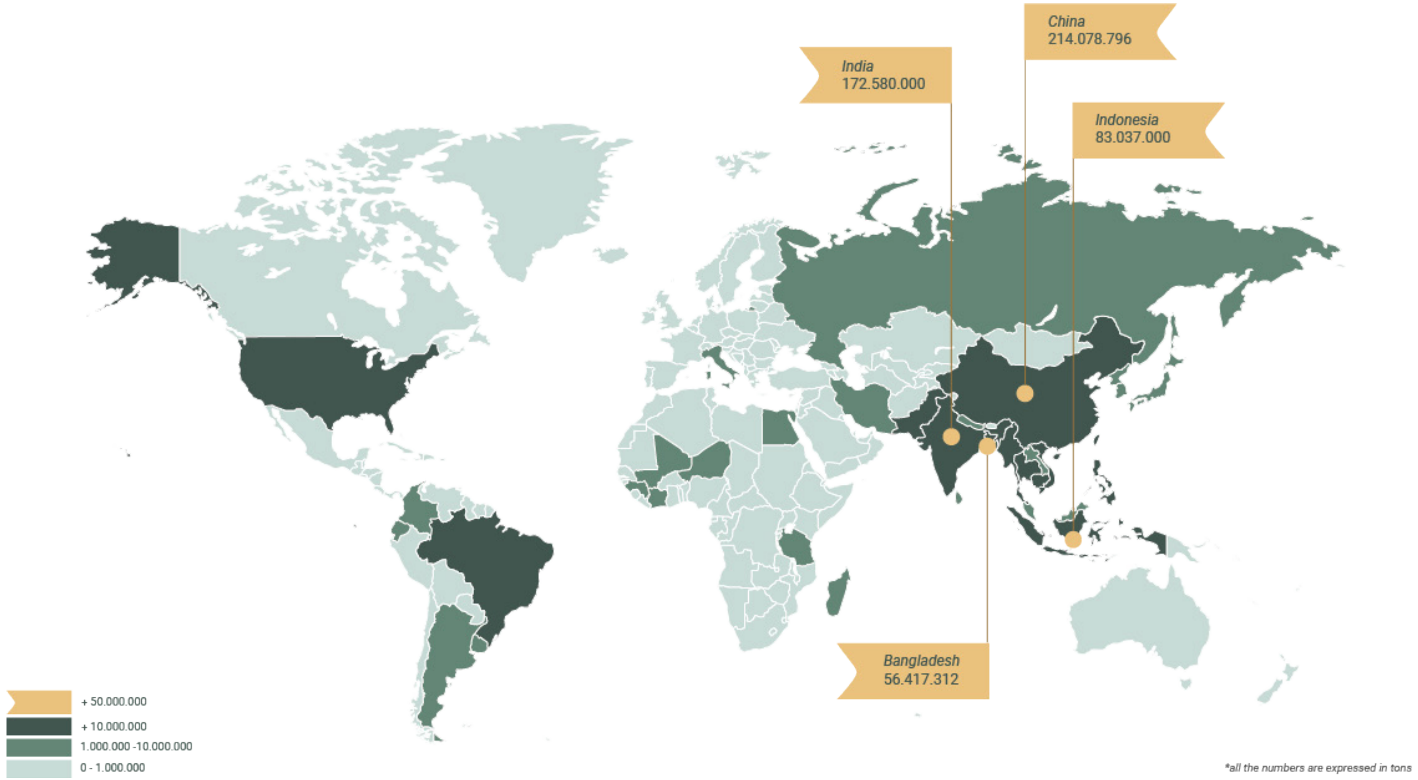


Fig.1 World rice production marked with flags are the four most productive countries, whereas the other countries has been divided into three production bands, the first represents the countries that produce more than 10.000.000 tons of rice, the largest producers at worldwide level. In the second band are represented the countries that have a production ranging from 1.000.000 tons to 10.000.000 tons, finally there are countries that have a production of less than 1.000.000 tons. (Fao, 2019)

In the world 155 million hectares of land are cultivated with rice.
From Figure 1 it is possible to understand which are the main world producers: at the first place there is China that produces 214.078.796 tons of rice per year, at the second place there is India with 172.580.000 tons of rice, at the third and the fourth place there are respectively Indonesia that produces 83.037.000 tons of rice per year and Bangladesh which produces 56.417.312 tons. In the graph the world has been divided into three production bands, the first represents the countries that produce more than 10.000.000 tons of rice, the largest producers at worldwide level. In the second band are represented the countries that have a production ranging from 1.000.000 tons to 10.000.000 tons, finally there are countries that have a production of less than 1.000.000 tons (Fao, 2019).

#consumption

Over the 90% of the rice produced is consumed in Asia, where it is essential for most of the population, including the 560 million hungry people who live there. The Green Revolution, through new hybrid varieties created with artificial selection techniques, has sustained an increase of consumption per capita in Asia, from 85 kilograms per year in the early 1960s to almost 103 kilograms in the early 1990s. During the same period, per capita consumption worldwide rose to 50-65 kg per year. Strong economic growth has stopped the growth trend in per capita rice consumption worldwide since the early 1990s in many Asian countries, especially China and India, because consumers have diversified their diets, preferring products such as meat, dairy products, fruits and vegetables. Over the last two decades, average per capita consumption worldwide has been around 65 kg, with a decline between 2001 and 2004 due to severe dryness in China and India. The result has been a reduction in global availability of more than 35 million tons, with a consequent increase in per capita consumption, returning to 65 kg in recent years. Household consumption expenditure data collected by the national sample of the India Survey Organization (NSSO) states that in the 1990s there has been a slight decline that has remained constant throughout India. In other Asian countries, such as Bangladesh and Philippines, per capita consumption continues to increase in all income groups in both urban and rural areas. National household consumption survey data collected from both the Philippines and Bangladesh between 2000 and 2010 supports this pattern. More rice is also being eaten by high-income groups in rural and urban areas. Rice use in Thailand, Vietnam and Malaysia is decreasing, unlike the Philippines and Bangladesh. Consumption outside Asia continues to rise steadily, with sub-Saharan Africa growth being the fastest. In the last two decades, per capita consumption of rice in sub-Saharan Africa has increased by more than the 50%. Similarly, it continues to grow steadily in both the United States of America (USA) and the European Union, because consumers have diversified their diets from protein-based to fiber-based regimes and because of a higher rate of Asian immigrants (Passini, 2014).

Fig.2 World rice consumption and export. (Statista, 2020) (Statista, 2019)

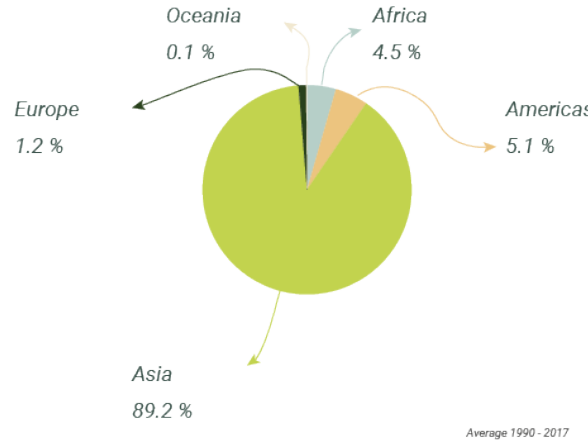
In 2019, 487 million tons of rice were consumed in the world, from Figure 2 it is possible to see that the populations that consume most rice are: China, first of all, India in second place and Indonesia in third place. Comparing the graph of consumption with that of production, it shows that the countries that produce the most rice are also those that consume it the most. The data are slightly different, however, if we talk about exports. As a matter of fact, the countries that export the largest quantities of rice are: India in first place, Thailand in second place and Vietnam in third place. Anyway, worldwide exports by country totaled 21.9 billion dollars in 2019 (Statista, 2019) (Statista, 2020).

Malnutrition and votes drove India's tough WTO stance. (2013, December 9). The Daily Star. https://www.thedailystar.net/news/malnutrition-and-votes-drove-indias-tough-wto-stance

#emission

The main greenhouse gases emitted by agricultural ecosystems are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), which contribute respectively to the 60 %, the 15 % and the 5 % to global warming. Among the agricultural activities, rice cultivation is the cause of the 18% of anthropogenic emissions of CH_4, indeed, the anaerobic situation of the submerged environment causes the emission of methane (CH_4), especially if the straw is buried near the submersion, while, during drainage, microbial nitrification and denitrification in the soil produce nitrous oxide (N_2O), mainly as a result of the application of nitrogen fertilizers. Due to the peculiar cultivation technique, rice represents, together with animal breeding, one of the agricultural sectors characterized by significant greenhouse gas emissions. One hectare cultivated with rice emits on average 3.52 kg of methane and 1.17 kg of nitrous oxide per year (Corinair methodology) (ARPA Veneto, 2017). For the same amount emitted, methane has a greenhouse effect on the climate about 28 times higher than carbon dioxide and nitrous oxide more than 300 times higher. A further pressure factor on air quality is related to the management of rice straw. Due to its high percentage of silica, rice straw can hardly be reused to feed animals or in the production of renewable energy, unlike straw from other cereals. In some types of soils, characterized by a slow degradation of the organic substance of crop residues, the traditional burning technique remains. This action has an extreme relevance on air pollution (Arpa Piemonte, 2017).

#METHANE EMISSION BY CONTINENT (CO^2 EQUIVALENT)



#TOP 5 METHANE EMITTERS (CO^2 EQUIVALENT)

Fig.3 World rice emission. The graph on the left represents the methane emission by continent, whereas on the right there are the five top methane emitters. All the datas are expressed in CO2 emission equivalent. (Fao, 2018)

The data concerning global methane emissions (Figure 3) from rice cultivation match, as it was possible to assume, with the countries with the highest production. In fact, Asia is the continent that emits the most methane with as much as 89.2%, which corresponds exactly to 440.399,76 gigagrams (CO_2 equivalent). To be more precise, the five countries with the highest rate of emissions are: China, India, Indonesia, Thailand and the Philippines (Fao, 2018).

2.2 The Italian scenario: data about rice cultivation and harvesting

Rice farming plays and has always played a very important role in Italy. More than 500 years have passed since rice cultivation began in the Po Valley. The cultivation of rice in Italy is mainly developed in Piedmont, Lombardy, Veneto and Emilia Romagna, following the course of the river Po. The Italian rice paddies are the northernmost in the world and the role of water, in our environments, plays an essential function as a thermal flywheel, in addition to irrigation. The need to keep the crop underwater for a long part of its life cycle has conditioned the territorial development of rice cultivation, which in fact is presented only in the Po Valley and in a few reclamation areas in the rest of the country, and has created the conditions for the construction of a network of channels for the distribution of water that runs for hundreds of kilometers and has ended up characterizing a particular environment today typical of the plain landscape. Italy is the first producing country in Europe; Italian rice paddies represent the 51% of the rice paddies in the European Union, the other producing countries are Spain, France, Greece and Portugal, Romania, Bulgaria and Hungary.
Italy is also the leading country in terms of production, covering about the 49% of the entire European production and having a completely unique range of varieties. In Italy, in fact, are grown both *Oryza sativa subsp. japonica* and *Oryza sativa subsp. indica* varieties and, among the japonica, some varieties such as Arborio, Carnaroli, Vialone nano of which Italy is the only producer in the world (Ente Risi, n.d.).

RISAIE ALLAGATE. (n.d.). Consorzio Di Bonifica Della Baraggia Biellese e Vercellese. Retrieved February 4, 2021, from https://www.consorziobaraggia.it/en/component/speasyimagegallery/risaie-allagate?Itemid=610

In Italy 220.027 hectares of rice are cultivated, from which 14.981.329 quintals of rice are harvested. This production has, however, consequences on the environment, in fact the Italian cultivation produces 118.003 gigagrams of methane. Today there are 4200 companies throughout the territory that deal with rice and cultivate about 132 varieties, although there are 200 types of rice that are registered in the national catalogue (Istat, 2020) (De Pasquale, 2019).

The 92% of the Italian rice cultivation area is located in two regions: Piedmont and Lombardy and in particular in the provinces of Pavia, Vercelli and Novara (Figure 4). However, it is also widely cultivated in Veneto, Emilia Romagna and Sardinia (Il 53 per cento del riso europeo è coltivato in Italia, 2018).

Fig.4 Italian most productive regions. (Il 53 per cento del riso europeo è coltivato in Italia, 2018)

2.3 Rice production in Vercelli province (Piedmont Region)

SiViaggia. (2020, September 14). L'essenziale è Barocco: alla scoperta di Novara e Vercelli. https://siviaggia.it/idee-di-viaggio/lessenziale-e-barocco-alla-scoperta-di-novara-e-vercelli/301040/

Located in the north-eastern area of Piedmont, the province of Vercelli (Figure 5) extends along the course of the river Sesia, from Monte Rosa to the Po, crossing the Baragge and the flat areas south-east of the capital. The landscapes, multiform and full of charm, vary from the massive alpine peaks, to the hills of Gattinara, covered by vines, woods and crossed by rivers, to the vast plains. Spectacular is the landscape of the rice fields that distinguishes the Vercelli area, one of the main producers of rice in Europe: plains symmetrically divided by rows of poplars and flooded with water for most of the year, reflecting the colors and shades of the sky. Several protected areas occupy the territory including the Lame del Sesia Natural Park with wetlands and gauze, the Po River Park (Alessandrino-Vercellese stretch), an ideal place for birdwatching and the Alta Valsesia Natural Park, an alpine park that extends to Monte Rosa (Vercelli, n.d.).

Fig.5 Localization of the province of Vercelli. (Provincia di Vercelli, 2019)

Vercelli is one of the most productive provinces in Italy in terms of rice cultivation. In fact, the 58% of the farms in Piedmont are located in Vercelli, which counts 917 rice producers. Here, 69.541,60 hectares of land are cultivated producing 4.867.911,74 quintals of rice of more than 100 different varieties (Bressani, 2019) (Sistema Piemonte, 2020).

#focus on rice varieties

Rice varieties? Sensory analysis answers. (2020, November 27). Italia Delight. https://www.italiadelight.it/rice-varieties-sensory-analysis-answers/?lang=en

In the world there are many species of rice and the selection and improvement done by man, in the course of time, have led to the constitution of varieties suited to different climatic conditions. It is possible to identify three main species from which derived many others, each one characterized by specific environmental needs for cultivation. One of these is the *Oryza sativa subsp. indica* species. These include varieties that are not very adaptable to low temperatures; they are mainly cultivated in environments exposed to natural flooding (lowlands systems) with tropical climate (e.g. southern China, South-East Asia, sub-Saharan Africa, Central and South America). The second one is the *Oryza sativa subsp. japonica* species whose derivatives show a good adaptability to low temperatures; they are mainly cultivated in regions with sub-tropical and temperate climate, such as, for example, Japan, Northern China, Korea, Central Asia, Europe, USA and Australia. The last one is *Javanica* or *bulu* (in Indonesia). It includes varieties traditionally cultivated in high altitude environments (Indonesia, Philippines and Madagascar), where temperatures are rather low during the growing season. These plants have recently become part of the group of tropical japonica varieties (Ferrero et al., 2008, 614).
The rice varieties of Vercelli are very linked to the most widespread culinary preparation in Northern Italy: “risotto”. However, the Indica varieties have also spread, with long grains and the semi-rounded Sushi varieties are spreading. The rice varieties which best suited to the climate conditions of the Vercelli area, are, intimately linked to risotto.
Riso di Baraggia Biellese e Vercellese is the first and only Italian rice Protected Designation Origin (PDO). Baraggia consists of vast prairies and heaths located on large plateaus at an altitude between 150 and 340 m, a part of which is characterized by rice farming, this is also the northernmost place where rice is grown. Four varieties of PDO rice for risotto are cultivated, one of these is “Carnaroli” rice, it has a large and pearly grain, it is considered the prince of risotto also by great chefs. Thanks to the high content of amylose, the grain remains consistent and keeps perfectly the cooking. The central pearl, that opalescent and slightly porous part inside the grain, allows it to better absorb flavors and condiments during cooking, an important characteristic for the preparation of risotto, which cooks close to its ingredients. Another variety of rice is “Arborio”, one of the most famous risotto rice in the world. It was born in Baraggia in 1946, in Arborio, the town to which it owes its name. In the panorama of Italian varieties, it has the largest grain, with its slightly square shape and a beautiful central pearl. The authenticity of the variety is the added value of “Arborio DOP di Baraggia”: about the 95 % of the rice cultivated and packaged as “Arborio” in Italy is actually “Volano”, a similar variety born in the Seventies. Thanks to the PDO regulations, the authentic and historical “Arborio” rice is grown in Baraggia. The third variety of PDO rice from Baraggia is called “Baldo”. It is slightly smaller than “Carnaroli” and has a particular characteristic: it is the only Italian rice for risotto that is crystalline, that is without pearl. The size and the good consistency of the

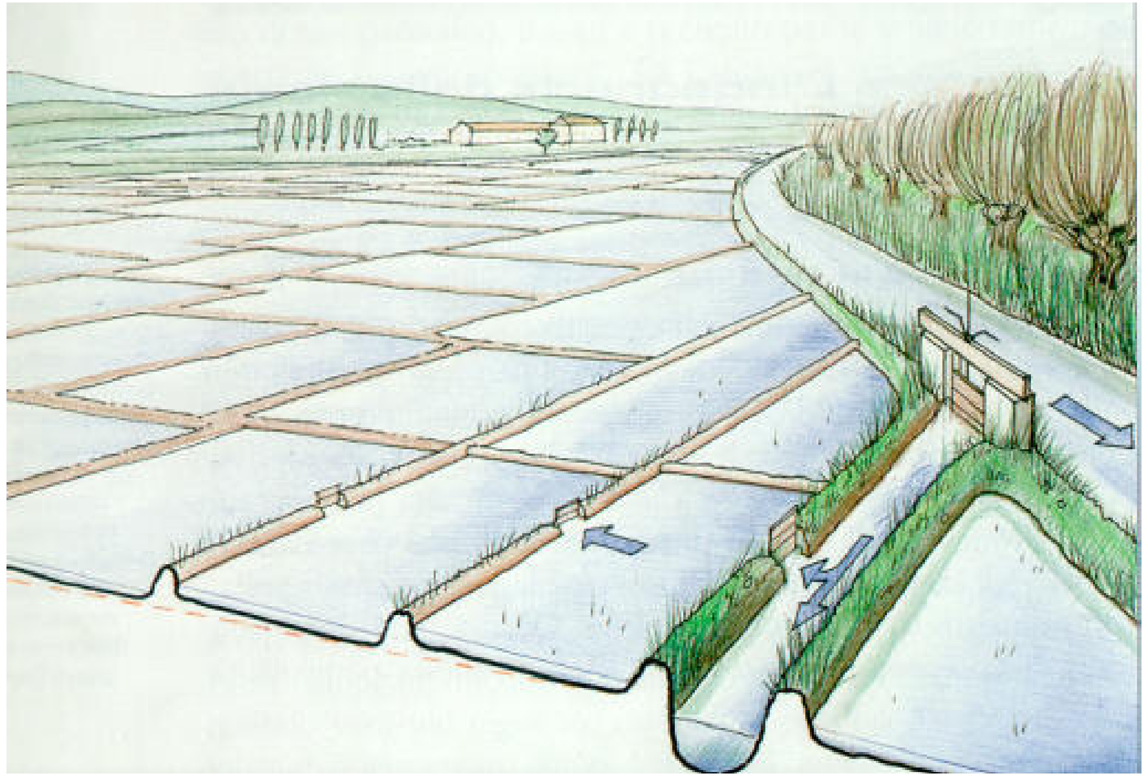
grain make it suitable for preparing excellent traditional risotto dishes, while the low content of amylose helps to promote a mantecatura without the addition of fat. The last variety is “S. Andrea di Baraggia” rice which takes its name from the historical Abbey of Vercelli, where it is used for the preparation of the typical local dish, panissa. It is a rice with a smaller grain than traditional risotto rice, but with an excellent consistency that gives the grain a good cooking hold. It is loved by chefs because it cooks in less time than other risotto rice, reducing the time of service, and because it releases a lot of starch in cooking, creating the creamy texture essential for the success of the “risotto mantecato all’onda”. Because of these characteristics, “S. Andrea” is also very appreciated for the preparation of arancini and supplì, which require a rice with a crispy core and a good cooking hold, but with the ability to bind the grains well together. For these particular and unique characteristics, “S. Andrea DOP di Baraggia” has been selected by Bocuse D’Or, the most prestigious international cooking competition, as an ingredient for the 2018 European finals in Turin (Le varietà di riso DOP, n.d.).

3.0 The rice paddy

After an overview of the data concerning the production of rice in the world, in Italy and in Vercelli in particular, this chapter analyzes the structure of rice field itself. The cultivation techniques used in this territory and the ecosystem services provided by the complex rice ecosystem will be explored.

To introduce these topics it is necessary to make a brief introduction explaining what is a rice field and how it usually works.
The paddy field is an agricultural land prepared to host the cultivation of rice and is characterized by a uniform working of the field that facilitates the inflow and the outflow of water coming from canals and ditches. The tanks that receive the water and the rice sowing are called chambers and they are surrounded by small earthen banks.
The water must fill all the chamber and it must drain in the next one, so the chambers are furrowed by small comb ditches which have the task of distributing the water and making it drain. The water comes from the ditch into the first chamber through the inlet vent.
The whole plot is surrounded in turn by larger embankments, service roads and, above all, the ditches that, opened and closed, serve to flood and collect the drainage water (L'ingegneria della risaia, n.d.).

Palazzo, G. (n.d.). Il reticolo delle acque nel Vercellese [Illistration]. Roberto Crosio. http://www.roberto-crosio.net/1_vercellese/reticolo_idrografia.htm

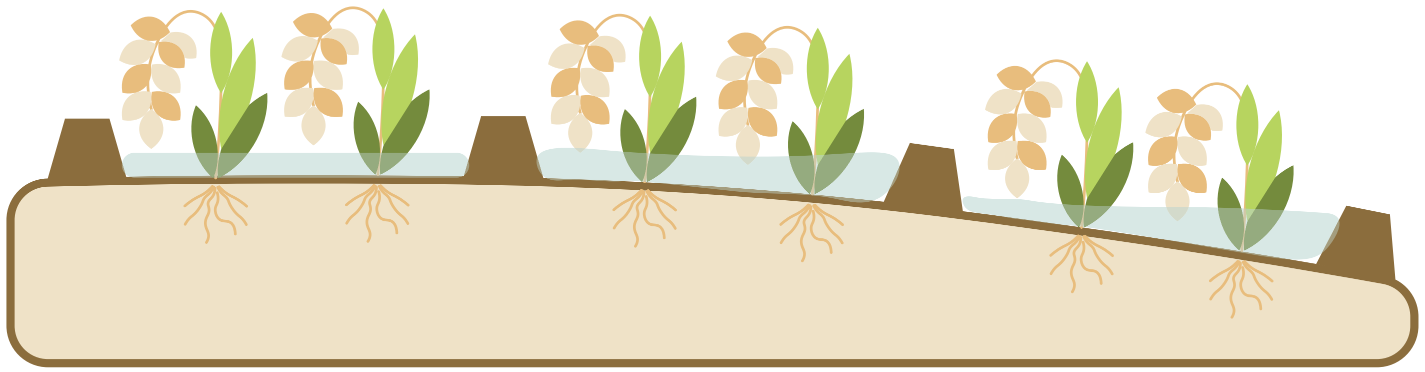


3.1 Rice paddy from an agricultural point of view

In the various production areas, rice is cultivated with very different techniques and systems according to the specific environmental, social and economic situations. From the environmental side, rice is grown under different climates all over the world including temperate, sub-tropical and tropical. Within a climate the weather can vary from arid and semi-arid to sub-humid and humid.
The main differences are essentially linked to the availability of water, the methods of planting the crop and the degree of mechanization available.
Rice is the only cereal able to grow without problems even in saturated or waterlogged soils.
With particular reference to water availability and the relationships that can be established between soil and water during the crop cycle, the world rice cultivation has been schematically classified into 4 main eco-systems: rainfed lowland, upland, deep water and irrigated (Ferrero et al., 2008, 617-624).

Rainfed lowland rice ecosystems (Figure 6) are found mainly in tropical and critical climate areas, where there are no conditions for the application of modern and expensive technologies, such as in river deltas, flood plain and inland swamps. Water supply to rice crops comes principally from rainfall so in these conditions, it is not possible to control the water level and rice, during its cultivation, is exposed to the risk of water shortage or flooding with a lot of water (50 cm deep and more), with alternations, sometimes sudden, of states of aerobiosis and anaerobiosis in the soil.
To catch and preserve rainfall for growth and production of rice plants, bunds and dikes are constructed around rainfed lowland fields.
Traditional long cycle varieties, sensitive to photoperiod and not very reactive to fertilization, are commonly cultivated. The crop is mainly planted by transplanting and only rarely by direct seeding.

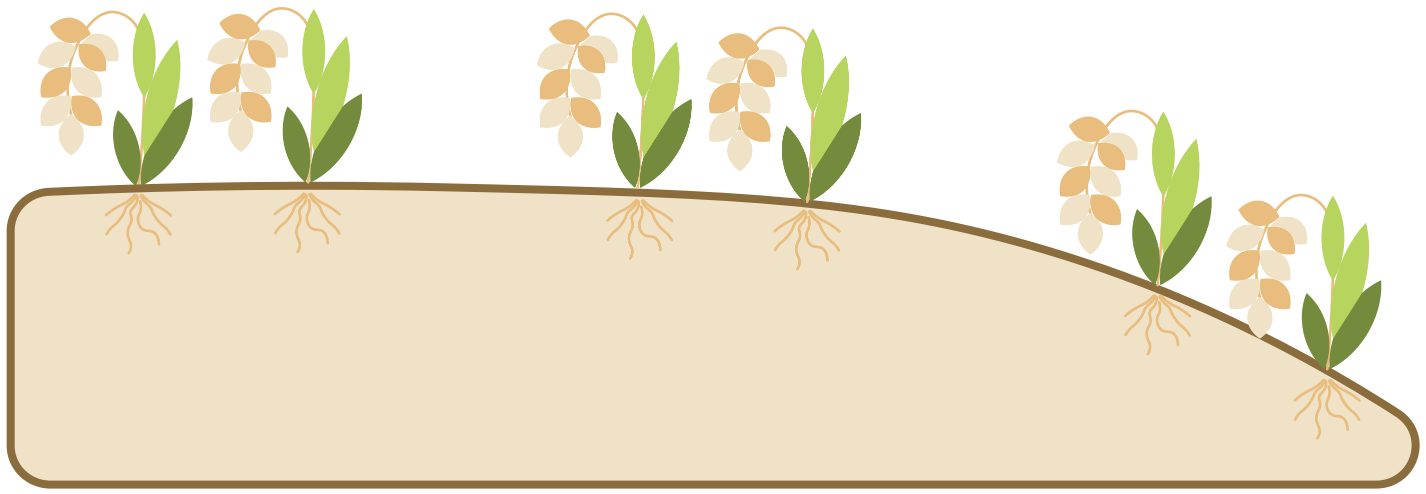
This system has significantly reduced in the last decade, however, it is estimated that it is still present on about 42 million hectares, mainly located in Asia and sub-Saharan Africa.
Yields of rainfed lowland rice remain low, about 1.5 to 2.5 tonnes/ha in most cases, in spite of a series of modern and high yielding varieties that were made available by international and national institutions worldwide.
The key drawbacks of this method are due to a high degree of uncertainty in the availability of water and reduced soil fertility; indeed, variability in rainfall and its distribution typically causes stresses of flood or drought in the development of lowland rainfed rice (Ferrero et al., 2008, 620) (Fao, n.d.).



- 32% of the rice growing area in the world
- 19% of total production
- Flat and gently sloping terrain with modest embankments
- No water regulation (from 0 to 30 cm depth)
- Water brought by rain
- Average production yield: 1-3 t/ha
- Mainly located in river delta regions, swampy areas and submerged plains of Asia and sub-Saharan Africa.

Fig.6 The graph represents the section of the rainfed lowland system with a summary of its main features (Ferrero et al., 2008, 620)

Rainfed upland rice fields (Figure 7) are found mainly in tropical climate areas, in this system rice is cultivated in fields placed from sea level up to the limits of steep mountain slopes. The lands can be flat or with slopes that can reach up to the 40%; rainfall is the main source of water supply to rice growth and development, soils are normally dry and draining and rarely the submersion lasts more than two days, during the whole cultivation cycle. Fields usually are not surrounded by bunds or dikes, only in some areas of India are made



- 10% of the rice growing area in the world
- 3% of total production
- Land from flat to steeply sloping (up to 40%)
- No water regulation
- Water brought by rain
- Average production yield: 1-4 t/ha
- Present in India, Bangladesh, in the humid hilly areas of West Africa and Brazil

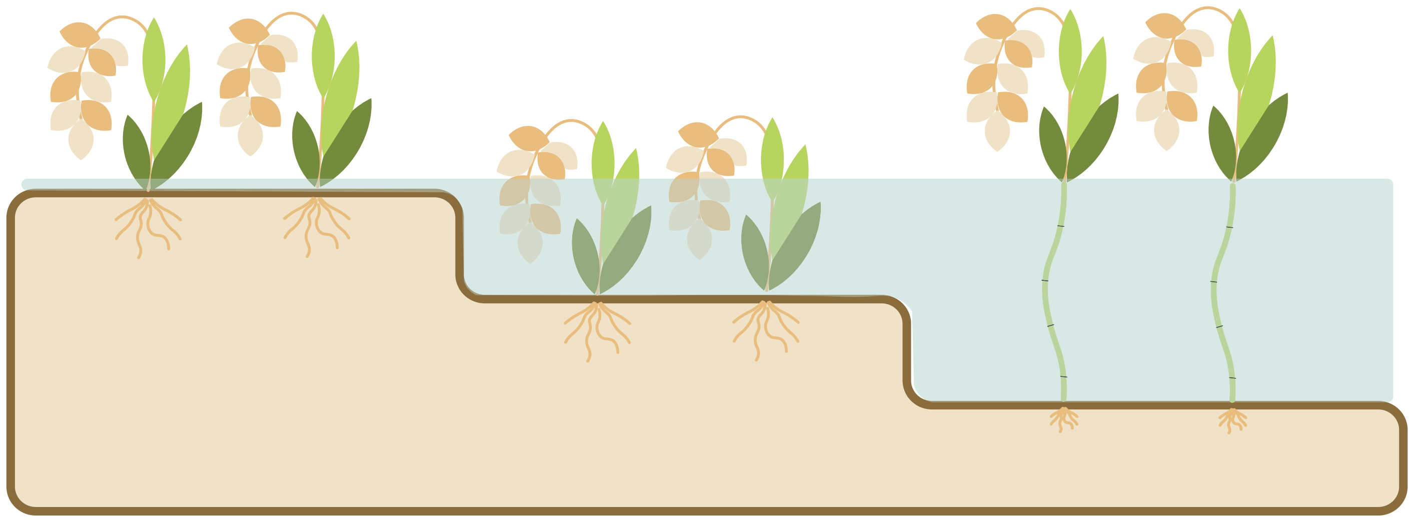
Fig.7 The graph represents the section of the upland rice system with a summary of its main features (Ferrero et al., 2008, 618-619)

modest embankments to try to retain the water that occasionally becomes available.
Rice is grown on dry soil, prepared as in the case of wheat or maize cultivation and sown just before the beginning of the rainy season.
Harvested areas of rainfed upland rice in Brazil decreased significantly since the 1980s, but that in Sub-Saharan Africa increased steadily. In the recent years, the harvested area of rainfed upland rice is estimated to be about 15 to 16 million hectares, about the 10% of the world's surface, but it is able to contribute no more than the 3% of total production. Under these conditions, average unit production often does not exceed 1.5 t/ha and does not prove to be significantly affected by the introduction of varieties with high production potential.
This agro-ecosystem is widely adopted in India and Bangladesh, in the humid hilly areas of West Africa and in the slightly undulating regions of Brazil. About 100 million people depend on these growing conditions for their food.
The main limits to production are due to the low fertility of soils, drought stress is the major factor affecting rice yield and production and the aggressiveness of diseases and weeds (Ferrero et al., 2008, 618-619) (Fao, n.d.).

Upland rice production in Vietnam
©VAAS | APAARI Community.
(2017, June 5). APAARI.
https://www.apaari.org/web/upland-rice-production-in-vietnam/

Deepwater/Floating rice ecosystems (Figure 8) are found in low lying areas in deltas such as the Ganges and the Brahmaputra, in India and Bangladesh, the Mekong in Vietnam and Cambodia, the Chao Phraya in Thailand and the Niger in West Africa, estuaries, swamps, and rivers' valleys, this is the typical system in environments where rice fields are subject to uncontrolled submergence for much of the crop cycle. This type of rice farming is also used in the wide flat expanses of the coastal regions of India, Bangladesh, Vietnam, and Indonesia, which are subject to daily flooding due to tidal ebb and flow.
During the early part of the rice growing season, water supply to the rice crop comes mainly from rainfall. However, as the cropping season progresses, water from swollen rivers and from high-lying ground inundated rice fields. The water depth is commonly variable from 50 cm to 1 meter and sometimes can reach 5 or 6 meters. In these latter conditions, known as floating rice, the plant is able to extend its culm until it comes out from the water surface.
The planting of the crop is mainly done by direct seeding on dry soil, before the rainy season; only rarely it is done by transplanting.
There were nearly 11 million hectares of deepwater and floating rice in the past. However, vast areas have been transformed through the construction of irrigation and drainage systems for the production of irrigated rice. In recent years, it is estimated that the harvested area of deepwater and floating is about 3 to 4 million hectares. Rice production in these ecosystems has not benefited much from research and development in the past. The average unit production is about 1.5 t/ha, even if with strong variations due to the unpredictable alternation of floods with periods of drought.
In these environments, the main problems in the cultivation of rice are related to the salinity of water and soil and sudden changes in water level (flash floods), also some problems are related to the strong environmental stresses, which limit the effects of the various factors of production (Ferrero et al., 2008, 620-621) (Fao, n.d.).

Fig.8 The graph represents the section of the deep water rice system with a summary of its main features (Ferrero et al., 2008, 620-621)



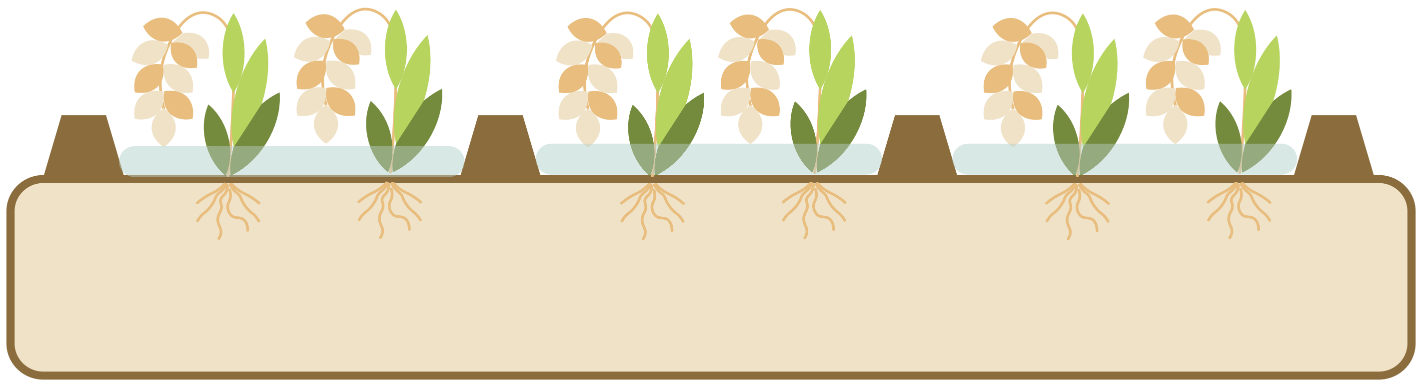
- 4% of the rice growing area in the world
- 2% of total production
- Flat or slightly sloping land without embankments
- No water regulation (from 0.5 to 6 meters depth)
- Water brought by rain or tides
- Average production rate: 1-1.5 t/ha
- Practiced in the deltas of rivers such as the Ganges and Brahmaputra, in India and Bangladesh, the Mekong in Vietnam and Cambodia, the Chao Phraya in Thailand and the Niger in West Africa. it is also practiced in the wide flat expanses of the coastal regions of India, Bangladesh, Viet-nam and Indonesia, flooded by the tides

Hines, P. J. (2018, July 13). How rice defeats the floodwaters. Science. https://science.sciencemag.org/content/361/6398/141.1

In temperate and most of the sub-tropical climate areas, rice is grown mostly under irrigated lowland ecosystems (Figure 9), once a year during the warm months; when temperature regimes are suitable for growth and development of rice plants. However, with available irrigation water, rice could be grown more than one crop per year in tropical climate areas. In arid and semi-arid zones of tropical climates, rice is planted under irrigated conditions only, but in humid and sub-humid zones, rainfall supplement irrigation water during the rainy season.
It is adopted on flat land, adequately leveled and surrounded by embankments, which can have a uniform layer of water adjustable in height according to the needs of the crop (from 2.5 to 15 cm).
In these regions the cultivation is mainly done by direct seeding, done by burying the seed, on dry soil, or with its distribution on submerged soil. In Asia the planting of the crop is done by direct seeding as well as by transplanting on wet or muddy soil.

The irrigated system is spread over about half of the world's rice-growing area and provides about the 75% of total production. It involves a large part of the rice surface area in North Africa (Egypt), North America, Australia and Europe, where cultivation is carried out only once a year. The spread of this system is linked to the creation of dams on the rivers to accumulate surface water and a dense network of canals to continuously irrigate the cultivated fields. In recent decades, in some countries, the development of irrigation systems has been achieved through the use of groundwater, taken from wells. The irrigated system has also found wide diffusion in Asia and South America.
The irrigated lowland rice production systems had benefited from substantial investment during the second half of the 20th century for the building of dams to divert the flow of the river and/or to store surface water and then channel it onto rice fields as well as the drainage systems to convert large part of deepwater and floating rice areas into irrigated rice production.
In late 1960s, farmers in several countries turned to

Fig.9 The graph represents the section of the irrigated lowland rice system with a summary of its main features (Ferrero et al., 2008, 622-624)



- 48% of the world's rice growing area
- 75% of total production
- Rice paddies surrounded by embankments
- Water region (5-15 cm depth)
- Water brought with irrigation (from rivers, lakes, pumped, etc.) and rains
- Average production rate: 4-10 t/ha
- It covers a large part of the rice area in North Africa (Egypt), North America, Australia and Europe, in recent decades it has also spread to Asia and South America, which thanks to the addition of this system are able to produce two or three crops per year.

underground sources and millions of irrigation wells were drilled to provide water for rice production. The irrigated lowland rice systems have benefited much from modern or high-yielding and hybrid rice varieties and associated improved rice technologies. In recent years, the harvested area worldwide from irrigated lowland rice systems was about 88 to 90 million hectares, due to the low risk of crop failure compared to other rice cultivation techniques. Average unit productions can vary from 4 to 10 tons/ha according to the means of production used. The highest production levels are recorded in Egypt, America, Australia and Europe, where it is frequent to obtain productions of more than 8 t/ha, with only one cultivation per year.
These results are possible thanks to the adoption of low size varieties, reactive to the contribution of nutrients and nitrogen in particular, having a good tolerance to biotic adversities and characterized by a high production potential.
The main problems encountered in the irrigated system of cultivation are represented by biotic adversities (weeds, insects and diseases), proper water management and environmental degradation related to a high input of inputs. This system is experiencing a significant loss of acreage due to urbanization and industrialization (Ferrero et al., 2008, 622-624) (Fao, n.d.).

LINEA VERDE INCONTRA NUOVAMENTE LE STAGIONI D'ITALIA. (2020, August 4). AILATI. http://ai-lati.it/2020/08/04/linea-verde-incontra-nuovamente-le-stagioni-ditalia/

The Italian cultivation system is precisely the irrigated lowland system which is also present in the rice fields of Vercelli, the territory that is considered in this study.
In this area are used different agricultural techniques, some more traditionals that results by the development of techniques used in ancient times, others, however, have been developed in recent years with the aim of water saving, or for the protection of biodiversity and the environment that are the techniques used for the cultivation of organic rice.
In the next subsections will be analyzed the different agricultural techniques starting from the ancient ones used at the beginning of the 1900's to the most modern organic cultivations.

3.1.1 Ancient cultivation

It can be said with certainty that the cultivation of rice appeared in Italy between 1450 and 1500, these dates are documented. Rice was imported from the East where the cultivation of this cereal was already widely practiced.
The origin of rice cultivation in Northern Italy is not very clear, however it is believed to come from Spain and then arrived in Naples after an invasion.
In Piedmont there is a late development of the culture of rice, in fact it began to spread in the 1700's and in 1866 was built the Cavour canal, the first big canal in Italy.
When rice was first cultivated in Italy, marshy lands were made cultivable and water from fountains was channeled. Therefore, were used the marshes of the province of Milan, Novara, Pavia, Mantua and some of the Adriatic coast such as Ravenna, Venice, Bologna, Rovigo, Ferrara and Udine. Rice then proved to be suitable for different types of soil, such as the Baraggia with cretaceous impermeable soil, the Brughiera made of permeable morainic gravel and the Lomellina made of loose soil.
The production of Italian rice, before 1860, was very low, the estimation correspond to 13.5 q/ha. Subsequently the production followed a growing trend, except for the first years of the 1900's when a decrease was recorded. It began to increase from the 20's on, to arrive in 1924

with an area cultivated with rice of 137.850 hectares and a total production of 5.920.800 quintals.
Instead, it is estimated that, in those years, world production was about 1.200-1.400 million quintals, in fact, there are no certain data about the production of some producing countries such as China (Strada, 1928).

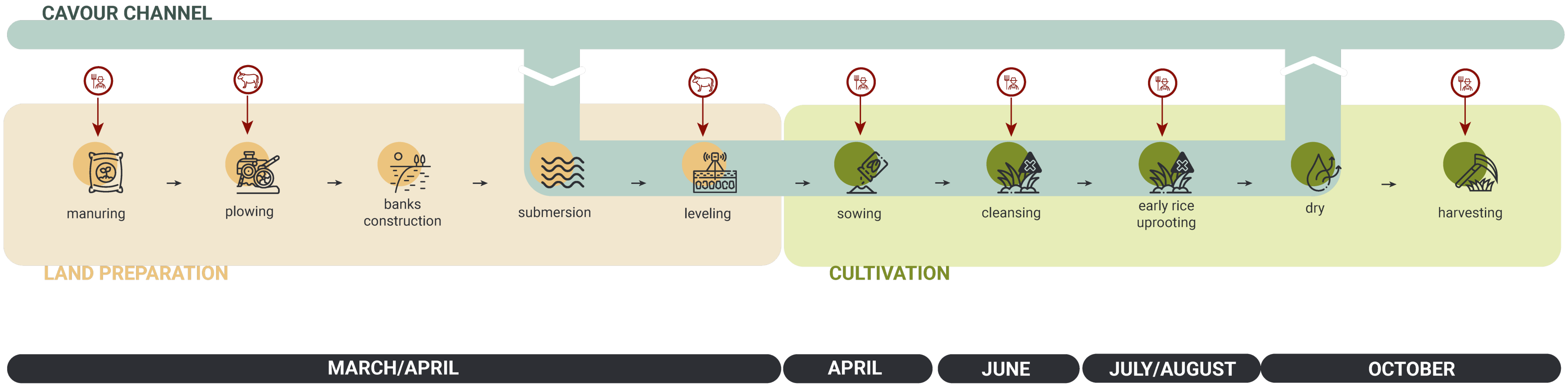
#traditional cultivation technique

As shown in Figure 10 the first operation that was carried out was the fertilization, the peasants or horsemen unloaded on the field piles of manure, which women then had to scatter with the forks, in case of chemical fertilization were towed on the field special fertilizer spreaders or the adventitious threw the fertilizer scatter, as if it were seed. Then the plowing began: on the field, in addition to the peasants with oxen and plow, there were women. At first the old furrow was deepened and the women with hoes intervened to clean it up and lower it. This served to keep the ground level.
The next step consisted in the construction of embankments, which were usually prepared by the workers with the shovel, they had to be well compressed to avoid landslides. They had drainage holes for the passage of water.
The water was then introduced to highlight the parts of land outcropping, lowered with hoes by women, while a rider further leveled the ground passing with a wooden plank pulled by the animal. This operation was particularly time and energy consuming because it was done barefoot in the still cold water of March-April.
At this stage the sowing was carried out,by particularly expert workers: the seeders.
The seeder had to stand at the center of the “pianón”, throwing the seed from one furrow to another, a particularly complicated task in rice fields where the water prevented a precise orientation. Therefore, branches were placed in the furrows as reference points; a row of seed sacks placed in the water also served to regulate the amount of seed to be thrown per unit of area.
In April, that is, before the beginning of the work of “monda”, it was often necessary to carry out maintenance and cleaning operations: storms or strong winds could uproot the newly born plants that were accumulated on one side of the paddy field, leaving entire areas uncovered, in these cases it was necessary to have small transplants.

Peluso, L. (2020, October 20). La storia dimenticata delle “mondine” del Sud. Quasi Mezzogiorno. https://www.quasimezzogiorno.org/news/la-storia-dimenticata-delle-mondine-del-sud/

In July and August, the women were sent both to uproot the “crodo” rice, a wild rice that matured early, and to turn over the weeds left in the furrows, to prevent them from taking root again. The work was considered by women particularly disgusting and tiring, in fact, the water level in the furrows was much higher.
For the harvesting both local men and women were employed and, to a small extent, at least in Lomellina, also immigrant workers.

Manual labor makes all processes take longer, but this avoids emissions from the use of farm machinery. However, there will still be methane emissions due to the fermentation of rice in water.
The rudimentary techniques used, moreover, cause a lower precision and therefore a lower yield. From this point of view, the positive aspect is that small pools are created in the field which allow some species to complete their life cycle during dry periods, thus preserving biodiversity (Crosio, n.d.).



FEATURES

The work in the paddy field involved a large number of people for a long period of time. For some operations, draught animals were used, and many were manual, which meant a longer duration for each step of the cultivation.

Biodiverity
The submersion creates a suitable habitat for some species and thanks to the low precision of the manual leveling, ponds are created where some species can complete their life cycle.

Emission
There are no emissions due to agricultural machinery but methane emissions due to the rice fermentation in water.

Time
All steps were done manually which takes more time

PROS

1. There are no CO_2 emissions from the use of agricultural machinery
2. The techniques used favor the cultivation of rice creates habitats for different species
3. Generating biodiversity

CONS

1. Methane emissions from rice fermentation in water
2. Long working time
3. Lower productivity caused by poor precision of the techniques used

Fig.10 The graph represents the agricultural operations carried out in the traditional cultivation of rice in a timeline. In the boxes below it is possible to find a brief description and the main characteristics, finally there is an analysis of pros and cons. (Crosio, n.d.)

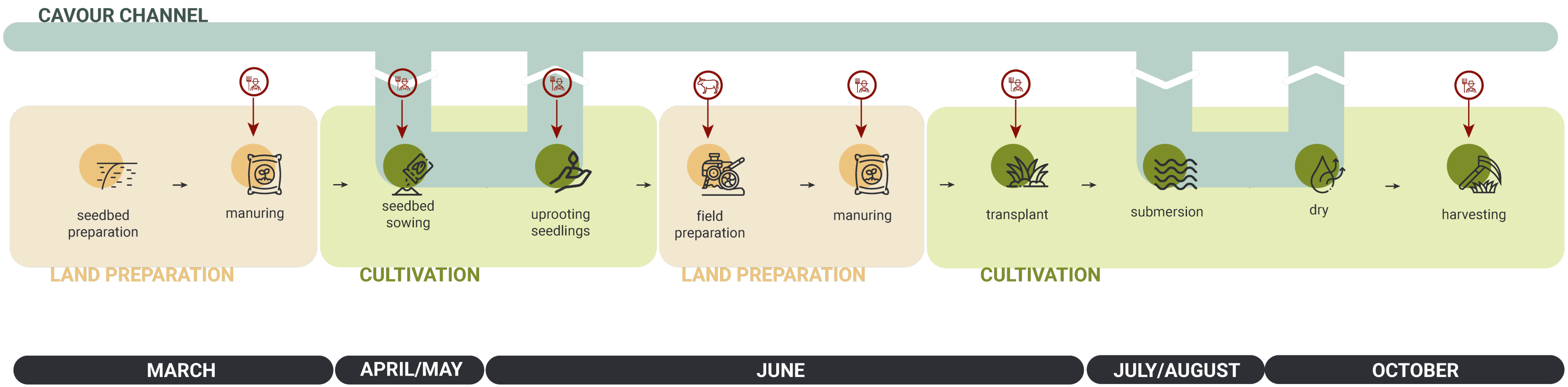
#transplanting technique

For the technique of transplanting (Figure 11) it was necessary first of all to choose the soil for the seedbed, because it depends on the success of the cultivation. Most of them chose a land adjacent to the field where transplanting was done.
A very important rule is the one concerning water, in fact this must be very hot, by using hot-water heaters in order to control the development of seedlings and have them ready in time for the operations.
In the phase of preparation of the seedbed the soil is harrowed twice in order to level the ground and flatten it, even twice if necessary.
Once the ideal soil is obtained, the fertilization of the seedbed is done, which must be abundant since rice here is subjected to a forcing. Both chemical fertilizers and manure were used, the latter was applied in autumn.
At this point the soil is ready for sowing, which will take place between the last week of March and half of April. It is recommended to put the seed in hot water one week before sowing.
The ratio between the surface of the seedbed and the surface of the field for transplanting is of 1/10-1/12, in fact it must be kept in mind that the seedlings in the seedbed must be thick in order to develop in height.
Regarding the control of weeds, only a few in this practice carry out the “monda” in the seedbed that could damage the seedlings, it is sufficient a proper water management in the early days.
In the month of June it is possible to proceed with the uprooting, the seedlings must have reached a height of 20/25 cm and must be strong enough to resist the tear. This operation was done manually by sinking the fingers in the ground, grasping the central rootlet and extracting it.
At this point the plants were transported by carts in the field and distributed along the furrows with very light sledges. These last practices had to be done quickly, but it was only after 1928 that the first transplanting machines arrived, however they did not give good results yet.
Before transplanting it is necessary to prepare the soil by harrowing, hoeing and ploughing. Afterwards the soil will be fertilized and therefore it will be ready for transplanting, which is done manually by first stretching the roots and sinking them in the soil.

This work was done by women who placed 4 or 5 plants in the furrows made by the stripe machine at about 15 cm of distance.
Once the plants have been transplanted, the rice field is submerged, first by keeping the water at a low level and then by gradually raising it.
Finally, in October the paddies are dried and the harvest takes place.

The transplanting technique proved to be a cost-effective technique due in part to the crops that were possible to grow before transplanting the seedlings into the field. However for this technique are necessary particular measures such as having hot water for the seedbed, and to minimize the time of manual work so that the seedlings are transplanted at the same age.
In fact if the seeding is done too slowly or if seeds are placed in a sparse way, it will result in a loss of productivity in the second case and it will be necessary to uproot too young or old seedlings in the first one (Strada, 1928).

Saviolo, E. (1937). Il trapianto del riso a file [Photograph]. Roberto Crosio. http://www.roberto-crosio.net/1_vercellese/habitat_antiche_tecniche.htm



FEATURES

The work in the paddy field involved a large number of people for a long period of time. For some operations, draught animals were used, and many were manual, which meant a longer duration for each step of the cultivation.

Biodiversity
The submersion creates a suitable habitat for some species and thanks to the low precision of the manual leveling, ponds are created where some species can complete their life cycle.

Emission
There are no emissions due to agricultural machinery but methane emissions due to the rice fermentation in water.

Time
All steps were done manually which takes more time

PROS

1. There are no CO_2 emissions from the use of agricultural machinery
2. The techniques used favor the cultivation of rice creates habitats for different species
3. Generating biodiversity

CONS

1. Methane emissions from rice fermentation in water
2. Long working time
3. Lower productivity caused by poor precision of the techniques used

Fig.11 The graph represents the agricultural operations carried out in the transplanting technique in a timeline. In the boxes below it is possible to find a brief description and the main characteristics, finally there is an analysis of pros and cons. (Strada, 1928)

3.1.2
Modern cultivation

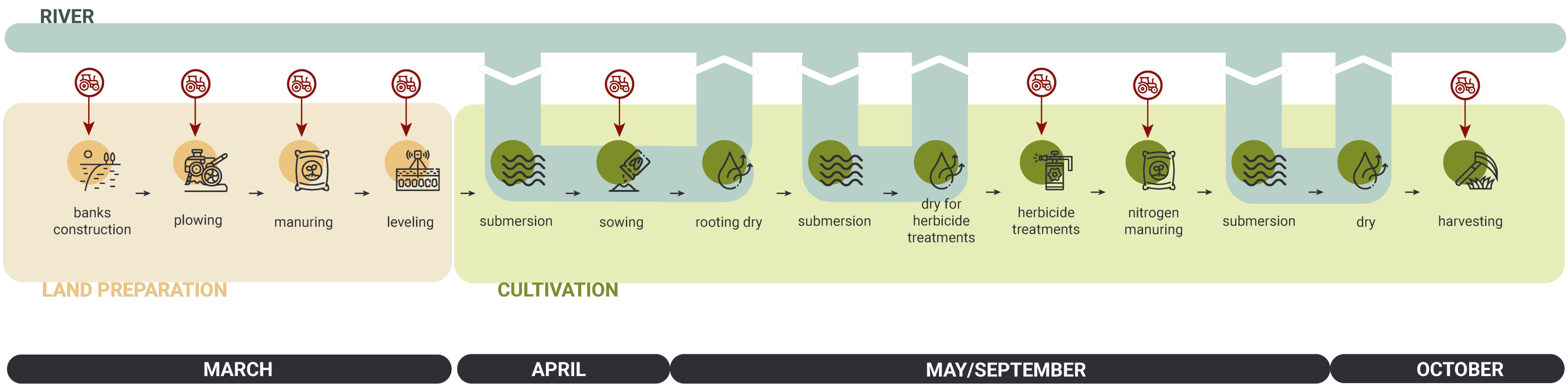
In Italy, nowadays, the most common cultivation technique is the one called “continuous submersion”, but during the years have spread other techniques which differ from each other mainly for the management of water.
Here are listed the two most used techniques, that of continuous submergence with seeding in water and that of dry seeding in rows with submergence in third-fourth leaf with turn irrigation.

#sowing in water and permanent submersion

In water-seeded cultivation with permanent submergence (Figure 12), the first operations that are done are those that are needed to prepare the field.
The embankments are then built, after which the field is worked with the plough and after a first fertilization the ground is leveled with a laser leveler in order to have a uniform soil.
Once the field is ready the rice field is submerged and the seeding is carried out.
At this point the paddy field remains submerged until the end of cultivation, before harvesting.
The thermal needs of the cereal have favored the spread of the continuous submerged cultivation system, benefiting from the thermal flywheel effect of the water blanket. This role is very important in the first phases of the cultivation cycle, when the thermal differences between day and night are considerable and the sensitivity of the crop is higher.
In fact, in this type of cultivation the paddy field is dried only twice during the process, once to allow the seedlings to take root and once for the fertilization operations and for the application of herbicides.

Compared to the techniques used in the past, agricultural machinery is now used for each operation, speeding up the process but adding emissions to those already present in the fermentation of rice in water.
There is also the contamination of soil and water by the use of chemicals and the loss of biodiversity due to the precision of new machinery such as the laser leveler which removes the possibility of creating natural pools of water in times of dryness to give the opportunity for some organisms to complete their life cycle.
Among the positive sides it is right to underline that submersion gives excellent nutritional effects, moreover there is a low concentration of weeds, early rice , cadmium and limited nitrate pollution (Ferrero et al., 2008, 298-323).

il ciclo di vita del riso | il Re del Riso. (n.d.). Il Re Del Riso. Retrieved February 4, 2021, from https://www.ilredelriso.com/il-ciclo-di-vita-del-riso/



FEATURES

The thermal requirements of the cereal have favoured the spread of the permanent submersion cultivation system, taking advantage of the thermal flywheel effect carried out by the water. The technique is suitable for all varieties of rice, the timing of the steps varies according to the variety of rice.

Biodiversity
Loss of biodiversity due to frequent dryness and laser levelling.

Emissions, pollution, production and timing
Innovations in agriculture have led to significant time saving and personnel reduction compared to ancient methods and also increased productivity, but at the same time have increased soil and water contamination and emissions into the environment.

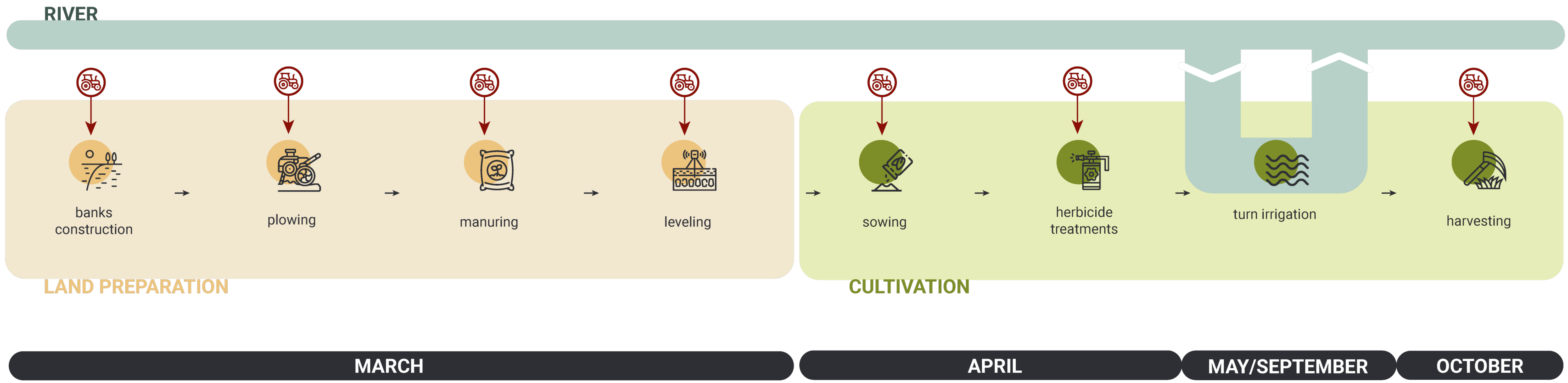
PROS

1. Submersion has good nutritional effects
2. There is a high degree of anoxia which helps to increase the efficiency of nitrogen fertilization
3. Early rice seed germination containment action
4. Substantial reduction of grass weed pressure
5. Limited nitrate pollution
6. Low presence of cadmium

CONS

1. Formation of methane and other gases
2. Increased risk of water contamination by herbicides
3. Wide use of water

Fig.12 The graph represents the agricultural operations carried out in the technique with sowing in water and permanent submersion in a timeline. In the boxes below it is possible to find a brief description and the main characteristics, finally there is an analysis of pros and cons. (Ferrero et al., 2008, 298-323)



FEATURES

It is a cultivation of rice on dry soil adopted in areas bordering population centers and in situations of water shortage. The technique is suitable for all varieties of Japonica rice especially the Sant'Andrea and Carnaroli.

Biodiversity
Loss of biodiversity due to frequent dryness and laser levelling.

Emission
There are emissions due to the use of agricultural machinery but the gas emissions due to fermentation decrease.

Contamination
Soil contamination due to intense use of fungicides.

Production
There are lower production costs and less water use.

PROS

1. Remarkable water saving
2. Production cost saving
3. Less gas caused by fermentation
4. Less water contamination

CONS

1. Higher nitrogen losses
2. Sensitivity to temperature changes
3. Risky for the accumulation of cadmium
4. Intensive use of fungicides
5. Strong conditioning by the rainfall trend

Fig.13 The graph represents the agricultural operations carried out in the technique of dry seeding in rows and submersion in third-fourth leaf with turn irrigation in a timeline. In the boxes below it is possible to find a brief description and the main characteristics, finally there is an analysis of pros and cons. (Ferrero et al., 2008, 298-323)

#dry seeding in rows and submersion in third-fourth leaf with turn irrigation

As it is possible to notice from Figure 13 the preparation of the soil is the same as the technique explained above.
The basic difference between the two techniques is in the management of irrigation.
In fact, the rice field is submerged in the tillering phase immediately after the fertilization from which not more than two or three days must pass, otherwise most of the fertilizer would be lost in the atmosphere.
Then irrigations are made by flowing, the irrigation shifts in conditions of loose soil are of 10-12 days, whereas they are extended to 14-16 in compact soils.
The process ends in October at harvest time.

LE VERE RAGIONI DELLA SEMINA IN ASCIUTTA. (2020, June 26). RisoItaliano | Il Portale Del Riso. https://www.risoitaliano.eu/le-vere-ragioni-della-semina-in-asciutta/

The first advantage given by this technique is the remarkable water saving, the biggest reason why it became widespread.
In addition, there are lower production costs, there are fewer emissions due to fermentation, and there is a decrease in water contamination as the amount used is reduced.
On the other hand, however, this technique suffers greatly from the conditioning of the rains that make it difficult to control dryness, the latter are the cause of loss of biodiversity, in fact many individuals need water to complete their life cycle.
Moreover, there are higher losses of nitrogen and the crops seem to be susceptible to some diseases that make it necessary the intensive use of fungicides (Ferrero et al., 2008, 298-323).

3.1.3 Biological cultivation

Organic rice cultivation is growing in recent times, involving more and more farms.
There are several practices that can be implemented, some of them are simply tricks or as they are called here good practices, such as crop rotation, green manure, false seeding and chain-harrow in post seeding.
There are also techniques that have recently been experimented in Italy, such as green mulching and mulching with biodegradable film.

#crop rotation

Crop rotation consists in a five-year plan in which different crops are rotated.
For organic rice the rule is to cultivate rice for three years, whereas two years the land must be destined to leguminous plants.
This technique is very important in order to maintain soil fertility, moreover, the sowing of alternative crops to rice creates the best conditions for the containment of weeds typical of submerged rice fields, as well as improving soil quality, especially for the significant

Vicia villosa | Veccia pelosa – Catalogo piante. (2020, May 8). Catalogo Piante. https://www.catalogopiante.it/piante/vicia-villosa_veccia-pelosa-022081/

amounts of organic nitrogen residues.
It can be affirmed that this technique is helpful to farms that want to reduce the use of fertilizers and pesticides respecting the organic farming method (Fasani, 2019).

#green manure

Green manure is the sowing of an intermediate crop to be buried before sowing the main crop to maintain or improve soil fertility. The seed is sown broadcast after the harvest of the rice, directly on the chopped straw, with doses of 30-50 kg per hectare.
Green manure provides nutrients such as nitrogen, phosphorus and potassium. The quantity of these elements varies according to the type of species

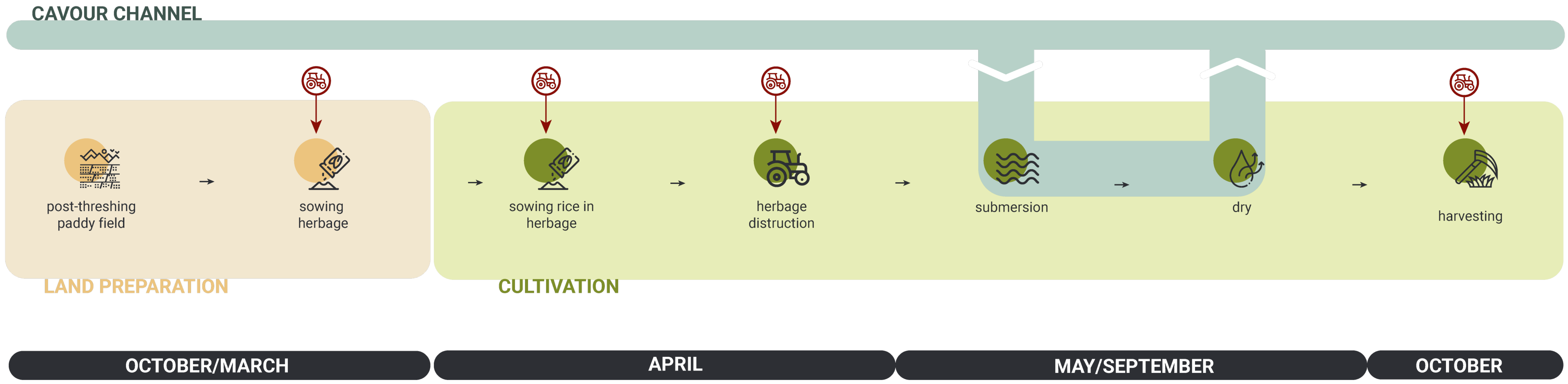
introduced, the most suitable for the Italian climate seems to be the hairy vetch which also allows a reduction of the fertilizer to be used. The use of leguminous plants, as they are nitrogen fixers, also allows the contribution of atmospheric nitrogen to the system.
Another important service provided by this technique is the improvement of the soil structure and its porosity, thanks to the contribution of organic substance.
The restoration of aeration conditions in autumn is fundamental to re-establish the normal conditions of chemical fertility as in rice fields the soil is in asphyctic conditions for long periods.
It is important to specify, however, that green manure does not have only positive aspects, it could create, in fact, a possible production of phytotoxic compounds resulting from fermentation and the immobilization of mineral nitrogen with a momentary reduction of its availability for rice (Ristec, n.d.).

#false sowing

In the technique of false seeding the paddy field is flooded with 1-2 cm of water, thus deceiving the weeds which, sensing the arrival of water, begin to germinate. After about 25-30 days the paddy field is dried and a light harrowing is carried out and the weeds are eliminated, only at this point the real seeding is carried out in the paddy field submerged by water.
Therefore, this technique is used to avoid the use of herbicides.
As sowing takes place later with this method, it is necessary to use early types of rice in order not to have a loss in productivity (Le tecniche di coltura del riso, n.d.).

#chain harrow in post sowing

The chain harrow is an extremely light harrow composed of elastic teeth that work on the first 4-5 cm of soil.
This technique allows the control of the “giavone”, the main weed in underground sowing, even more than the 90%.
The first two steps must be done in pre-emergence.
After the appearance, before intervening again, the crop must have reached the stage of 2-3 leaves.
This technique is used in post-seeding for burying



FEATURES

The green mulching, exploits the mix of lawns that compose the autumn-winter herbage (not mulched but left in the field) to create, through the use of a roller that lies and crushes the grass on the ground, a real natural cover.

Biodiversity
Promotes the development of biodiversity through minimally invasive techniques

Emission
There are emissions due to the use of agricultural machinery

Contamination
Contamination is reduced because no chemicals are used.

Production
Less rice is produced compared to a conventional technique.

PROS

1. Reduces the development of pests
2. Preserves soil moisture by counteracting evaporation
3. Nitrogen runoff reduction
4. Surplus of organic substance
5. Improvement of the soil structure
6. Herbicides are not used

CONS

1. If the grassland is not felled at the right time, the crop will rise again
2. Increased presence of insects
3. The cover competes with rice
4. It is difficult to manage the banks
5. Decrease in production

Fig.14 The graph represents the agricultural operations carried out in the green mulching technique in a timeline. In the boxes below it is possible to find a brief description and the main characteristics, finally there is an analysis of pros and cons. (Agronotizie - Notizie per l'agricoltura, 2017) (CREA - Ricerca da vedere, 2020)

Zaccaria, C. (2019, June 21). Pacciamatura verde. Riso Zaccaria. https://www.risozaccaria.com/pacciamatura-verde

seeds, herbicides and fertilizers.
But above all, as already specified, it is used by farms that want to limit the use of herbicides to eliminate weeds without the application of chemicals (Erpicatura: cos'è e perché viene fatta, n.d.).

#green mulching

In order to cultivate rice with the technique of green mulching (Figure 14) it is necessary to sow a herbarium just after the harvest of the previous crop, therefore in October.
Generally nitrogen fixers are used because thanks to their properties they give more quality to the soil and once the herbage has been cut down it prevents the growth of weeds.
This operation takes place in April, after having sown the rice in the herbage.
Finally the rice field is submerged and is left in this state

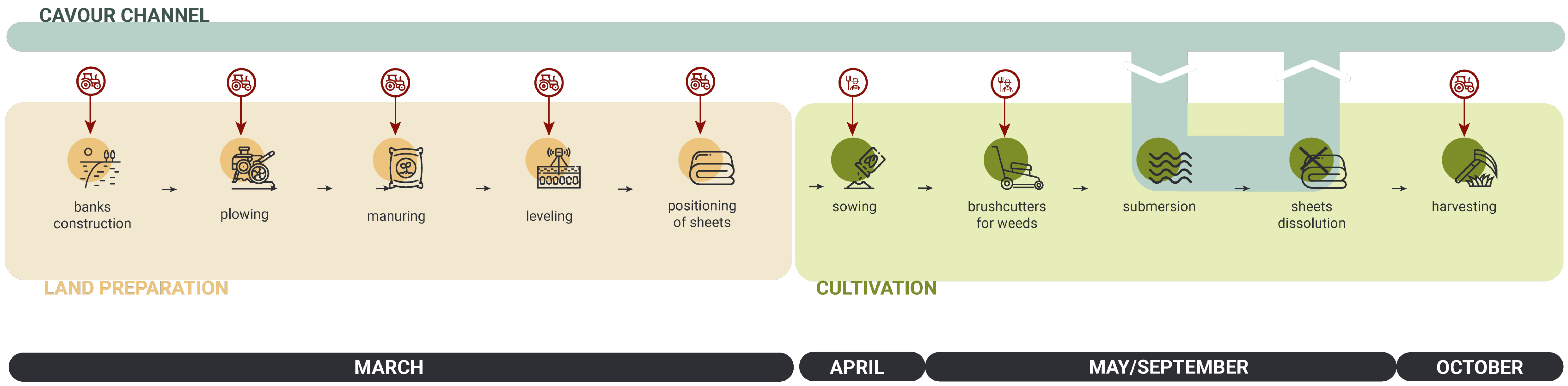
until harvest time.

As it can be seen in the diagram (Fig.14), this technique requires few operations and human intervention is minimal. This, in addition to the non-use of chemicals, promotes the development of biodiversity but makes it difficult to manage the banks.
The natural control of weeds, makes it possible to avoid the use of herbicides and thanks to the nutrients provided it is possible not to use fertilizers. In this way, contamination of water and soil is avoided.
However, some measures are necessary, it is important to manage the felling of the grass at the right time, otherwise the crop planted in autumn would grow again. Moreover with this technique it has been proved that the quantity of rice produced is lower (Agronotizie - Notizie per l'agricoltura, 2017) (CREA - Ricerca da vedere, 2020).

#mulching with biodegradable film

In contrast to the previously analyzed technique, the same soil preparation operations are used for this type of mulching (Figure 15) as for traditional cultivation. Therefore, first of all embankments are built, then ploughing and fertilization are done. Finally, the land is leveled and biodegradable films are laid on the fields in rows with corridors that divide them.
For sowing, holes are made on the sheets and some seeds are dropped inside.
Periodically it is necessary to pass between the films with grass cutters to remove weeds.
The paddy field is then submerged and left in this condition until harvest time, in the meantime the films dissolve in the soil.

This technique is more expensive than the others because, for example, the biodegradable sheets used are not cheap. In addition, rice productivity is lower than other techniques.
On the other hand, however, there is a lower use of fuel since some operations have to be done manually during cultivation which makes these activities longer.
Herbicides are not used and there is a lower use of fertilizer which means there are no contaminants in soil and water, the latter is used in less quantity with this technique.
There are however, some aspects to take into



FEATURES

This type of mulching is an innovative system of rice cultivation, made through large sheets that cover the paddy field, fighting the growth of weeds.

Biodiversity
Biodiversity is at risk because birds are a problem as they could feed on seeds

Emission
There are emissions due to the use of agricultural machinery in the first period.

Contamination
Contamination is reduced because no chemicals are used.

Production
Less rice is produced compared to a conventional technique and some steps take more time because they are done manually.

PROS

1. Less use of manure
2. Water saving
3. Lower fuel consumption
4. Poor formation of mold and fungal attack
5. Herbicides are not used

CONS

1. Expensive technique (film and manpower)
2. Manual sowing
3. The wind could lift the sheets
4. Birds could eat the seeds
5. Decrease in production

Fig.15 The graph represents the agricultural operations carried out in the mulching with biodegradable film technique in a timeline. In the boxes below it is possible to find a brief description and the main characteristics, finally there is an analysis of pros and cons. (Riso Vignola, n.d.) (LA PACCIAMATURA CHE NON CONVINCE, 2020) consideration, in fact the birdlife could eat the seeds and the sheets could be moved or lifted by the wind (Riso Vignola, n.d.) (LA PACCIAMATURA CHE NON CONVINCE, 2020).

Repetti, O. (2017, October 20). La pacciamatura sul riso biologico taglia i costi di acqua e diserbo. Terra e Vita. https://terraevita.edagricole.it/tecnica-e-tecnologia/colture/la-pacciamatura-sul-riso-biologico-taglia-i-costi-di-acqua-e-diserbo/

3.2 Rice paddy from an ecological point of view

The rice field is considered a temporary wetland.
A wetland is characterized by the presence of water that could be found at the surface or in the root zone. They have particular soil conditions and consequently they support the growth of a specific type of vegetation.
But since the paddy field is often dried it keeps the characteristics of a wetland for a short time, for this reason it is considered a temporary wetland, which, as a matter of fact, are characterized by intermittent flooding, the predominant feature of this category indeed is that annually or unpredictably there is a complete absence of water.
Rice paddies represent 15% of the world's wetlands and as a wetland, the rice field brings numerous benefits such as the creation of habitats for many species, thus enriching the area with biodiversity. This richness then gives life to a landscape with a high aesthetic value, making possible also many educational activities.
At the same time, however, the production of rice through a traditional agricultural system produces some services (Figure 16) that have an impact on the services produced by the paddy field as a wet ecosystem. As a matter of fact, agricultural process involves the use of some measures to improve productivity. Repeated dryness, for example, contribute to the creation of an ecological trap for some species, this improvement and others have completely destroyed the ecological character of wetlands. However, this does not apply to biological farming techniques, which are less invasive.
In the following, all ecosystem services produced by paddy as a wetland and as an agroecosystem will be analyzed in detail (Calhoun, et al., 2016) (Lawler, 2001) (Verhoeven & Setter, 2010).

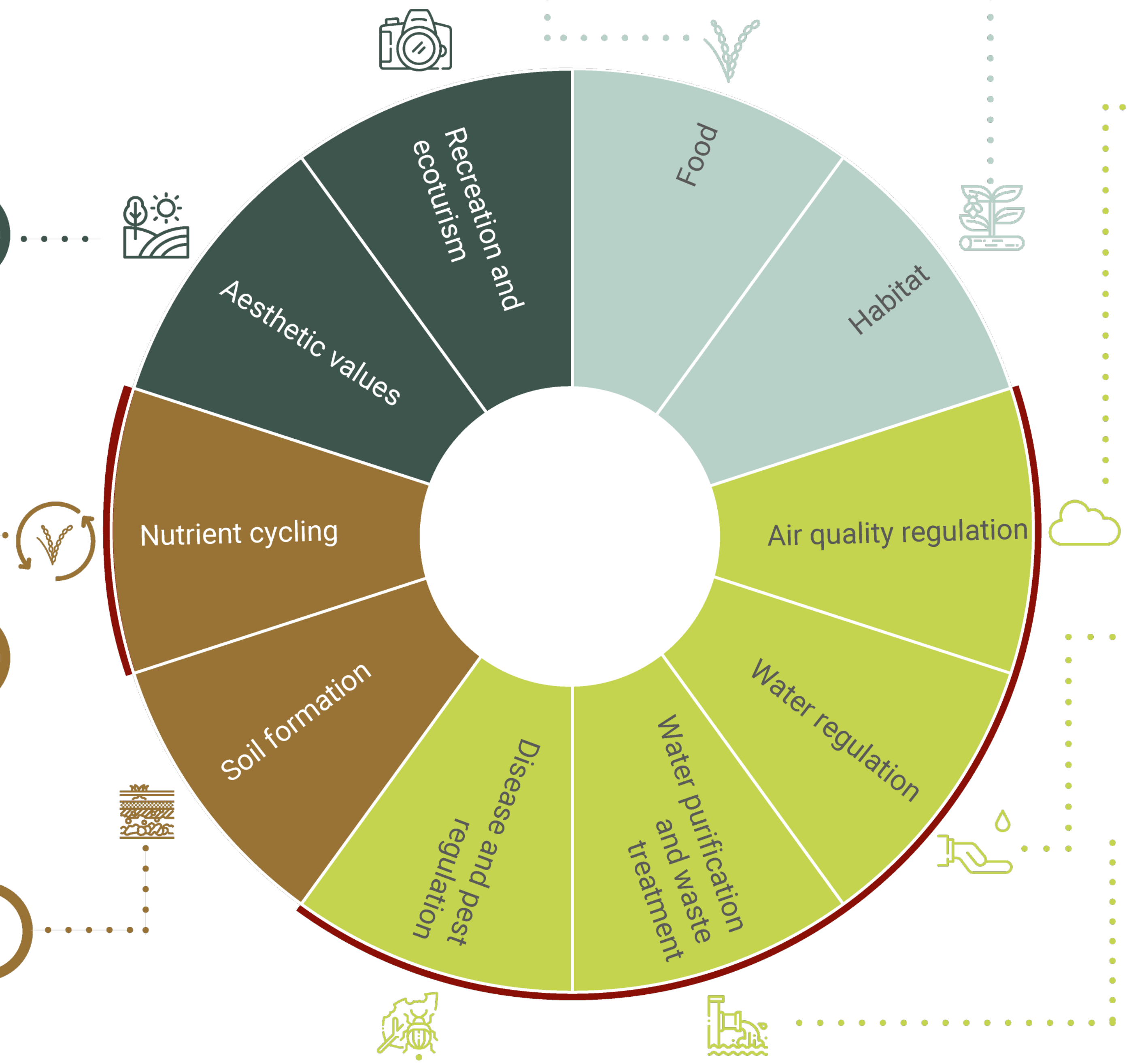
Fig.16 The graph represents the ecosystem services provided by the rice field system with a brief description (Ferrero, Angelini, & Ponti, Il riso, 2008)(Ente Risi, n.d.)(Ministry for the environment, n.d.) (Ferrero, Angelini, & Ponti, Il riso, 2008) (Ente Risi, 2012) (Queensland Government, 2013) (European Environment Agency, 2012) (Ferrero et al., 2008, 200-203)(The International Ecotourism Society, n.d.)

Ecotourism is a responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education. In fact in the rice fields you can carry out various activities such as birdwatching or educational activities for schools.

The landscapes of rice are characterized by horizontal expanses of fields divided into geometric patterns. Rice landscapes offer their most spectacular appearance in late spring and summer, when the chambers are flooded and the reflections of the sky and trees create unusual optical effects for the countryside.

Soil plays a crucial role in nature's cycles, including the nutrient cycle, which involves how much soil organic matter is taken up and stored in soil. In paddy soil the different redox conditions compared to agricultural soils alter the cycle of the main nutritionally interesting components.

Soil is most important in ecological function as the basis for the growth of terrestrial plants, including supplying nutrients, water, temperature moderation, and support. Plants are the main source of food for humans, animals and birds. Therefore, most living things on land depend on soil for their existence.



Rice today is the staple food crop of over 3 billion people. The production of this cereal is so developed because it can be successfully grown in a wide range of agro-ecological conditions and in various environmental conditions, hundreds of thousands of rice varieties have been produced for the production of rice and to satisfy the tastes and desires of different people.

Animals and plants in rice paddies depend on each other for survival: they are part of a food chain. Rice fields are the perfect habitat for a large number of plant and animal species such as algae, plants, fish, amphibians, reptiles, molluscs, crustaceans, worms and insects. The presence of these species supports the life of protected birds and the presence of migratory birds that otherwise could not winter in these areas.

Good outdoor air quality is fundamental to our well-being and for the natural environment. Rice paddies contribute to the diffusion in the atmosphere of planet earth of about 100 million tons of methane per year, as a result of fermentation processes, in anaerobic environment, of the flooded soil.

Rice requires a good availability of water for the development of its plant, and water management becomes very important for the success of the cultivation.
The network of canals, however, requires adequate maintenance to meet irrigation needs while respecting an economic management of irrigation.

The water that submerges the rice fields comes from artificial channels channeled by natural watercourses. When the field dries out, the water returns to the river and will contain traces of chemical pesticides.

Crop pests, including herbivores, frugivores, seed-eaters, and pathogens (specifically, fungal, bacterial and viral diseases) decrease productivity and in the worst case can result in complete crop loss. It has been estimated that biotic factors alone can cause an average production loss of 50%, despite chemical protection of the paddy field.

3.2.1 Food

The first ecosystem service produced by the rice field as an agricultural system is the production of a food product: rice.
This ecosystem service is produced both by the wetland as it creates the right conditions for its growth but also by the rice agroecosystem that makes possible its controlled production.

Rice is a graminaceous plant and is a ‘cereal’, a literary and historical term generically indicating various plants of the gramineae, whose fruits, rich in starch and protein substances, provide flours of nutritional value.
The world’s three leading food crops are rice, wheat, and maize, which together directly supply more than the 50 % of all the calories consumed by the entire human population.
Rice stands in second place after wheat as the most widely cultivated cereal.
Rice provides 21% of the world’s per capita human energy and 15% of its per capita protein. Although rice protein is high among cereals in nutritional quality, the protein content is modest. Minerals, vitamins, and fiber are also provided by rice, although all components except carbohydrates are reduced by milling (IRRI, n.d.).
Rice today is the staple food crop of over 3 billion people. The production of this cereal is so developed because it can be successfully grown in a wide range of agro-ecological conditions, from rainy areas to deep underwater environments up to several meters high.
In various environmental conditions, such as tropical, subtropical and temperate climates, hundreds of thousands of rice varieties have been produced for the production of rice and to satisfy the tastes and desires of different people (Ferrero et al., 2008).

The seed of rice is formed by different parts, the husk, that is a multi-layered involucre, tending to brown or yellow color. It constitutes the 20% of the total weight.
The chaff is a layer which covers the grain under the husk and is rich in nutritional elements and proteins, it makes up the 8-9% of the whole grain.
Continuing towards the inside there is the endosperm, a layer also called albumen rich in proteins, vitamins and starch. The last part is made of the germ or embryo, it will give life to a new rice plant and it is therefore a very important part of the grain (Riso – Guida completa: origine, storia, varietà, coltivazione, lavorazione, cucina, 2019) (Ente Risi, n.d.).
Carbohydrates constitute about the 80 % of the rice grain’s nutritional composition, protein about the 7 %, lipids about the 0.5 % and water the 12 %. As far as the vitamin content is concerned, the most commonly mentioned are water soluble vitamins: thiamine (vitamin B1), riboflavin (vitamin B2), niacin (vitamin PP) and folic acid (vitamin B9); as far as the macroelements are concerned, they are: phosphorus, potassium, magnesium, sodium and calcium, and as for the trace elements: copper, selenium, zinc and iron. Studies on the grain structure have shown that lipid, thiamine, riboflavin and niacin concentrations gradually decrease from the outer part of the grain towards the middle (Ferrero et al., 2008, 136-139).

Altroconsumo. (2021, January 18). Come testiamo il riso. https://www.altroconsumo.it/alimentazione/fare-la-spesa/come-testiamo/prove-test-riso

3.2.2
Habitat

The rice field as wetland produces habitat, because it creates ideal conditions to host different animal species. However, this possibility is endangered by the techniques used to produce rice.

The presence of algae, fish, amphibians, reptiles, mollusks, crustaceans, worms, and insects supports the life of protected birds and the stopover of migratory birds that otherwise could not winter in these areas.
The first species to appear in rice fields at the beginning of the rice season are waders. The rarest are the *Calidris minuta*, there are also the *Numenius arquata* and the *Alidris ferruginea*. Including the rather elegant *Himantopus himantopus* to the *Limosa limosa*, from the small and camouflaged *Gallinago gallinago* to the *Tringa nebularia* and the *Tringa erythropus*, the shapes are sometimes distinct.
The rice field, especially when the seedlings begin to become taller and thicker, is the ideal habitat for *Gallinula chloropus*. Another rallid that runs on the water is the *Fulica atra*. But the real protagonists of the rice field are the ardeids, the family of the herons and the egrets. These two birds are the ones that mostly attract the attention of those who visit the rice field. The *Ardea cinerea* strikes for its majesty and elegance. The *Egretta garzetta* is immediately noticeable even in the distance for its white plumage. Another common ardeid in rice fields is the *Nycticorax nycticorax*, white and gray with long feathers that descend from the head.
The grey heron is, together with the egret, the most frequent heron. In fact, the great white heron is seen in rice fields mainly from late autumn to late winter, and possibly in spring.
Along the canals and resurgences it is possible to see the *Alcedo Atthis* with its unmistakable trill and the precious metallic blue plumage of its back. The most frequent observations are those of the *Buteo buteo*, the *Circus aeruginosus* and the *Falco tinnunculus* among the birds of prey.
Since a few years, the Italian rice field also hosts the *Threskiornis aethiopicus*. It is a relative of pelicans that, like herons, feeds on frogs, fish, snakes and mice. Its presence was exceptional until 4-5 years ago, while today it is a constant presence throughout the rice-growing territory.
For life, the animals and plants in the rice fields depend on each other: they are part of the food chain.
The preservation of the rice paddy ecosystem ensures a better quality and quantity of food for farmers and ensures the conservation of biodiversity.
In general, however, the presence of birds can be considered a good indicator of the environmental quality of a rice field (Strada Del Riso Vercellese, n.d.) (L'ecosistema delle risaie, 2019) (Ente Risi, n.d.).

Mariotti, A. (2019, June 20). Le risaie poco allagate fanno scomparire aironi e rane dal Parco del Po fra Alessandria e Vercelli. La Stampa. https://www.lastampa.it/alessandria/2017/04/09/news/le-risaie-poco-allagate-fanno-scomparire-aironi-e-rane-dal-parco-del-po-fra-alessandria-e-vercelli-1.34614777

3.2.3
Air quality regulation

For our well-being an healthy outdoor air quality is fundamental. A person inhales about 14.000 liters of air per day on average, and the presence of pollutants in it can adversely affect the health of people. The most vulnerable are people with pre-existing respiratory and cardiac problems, asthma, young people, and older

people.
Studies have shown that the natural world can also be adversely impacted by low air quality. When air contaminants come into direct contact with plants, or when animals inhale them, ecological damage can occur. It is also possible to deposit toxins from the air on land and water.
They can leach from the soil into waterways or be absorbed by plants and animals. Our climate may also be influenced by poor air quality: some emissions have a warming effect, whereas others lead to cooling. These effects on human health and the environment from poor air quality can, in turn, have negative economic impacts. For example, we incur substantial costs for hospitalization and medical care, premature deaths, and missed days at work. The productivity of our agriculture and forestry industries can be diminished by damage to soils, trees, and waterways (Ministry for the Environment, n.d.).

In rice paddies, rice is cultivated under water, since this allows both to meet the water needs of the crop and to perform a thermoregulating function, limiting the temperature changes that the plant would undergo. The situation of anaerobiosis of the submerged environment causes the emission of methane (CH_4), while microbial nitrification and denitrification in the soil produce nitrous oxide (N_2O), especially during applications of nitrogen fertilizers. Because of this peculiar cultivation technique, rice represents, together with animal husbandry, one of the agricultural sectors characterized by significant greenhouse gas emissions. In fact, one hectare cultivated with rice emits on average 3.52 kg of methane (CH_4) and 1.17 kg of nitrous oxide (N_2O) per year (Arpa Piemonte, 2014).

So, air quality regulation is strictly influenced by soil condition crated by the process of producing rice.
As a consequence, it is possible to affirm that rice agroecosystem produce a service that has a negative impact on the environment.

3.2.4 Water regulation

Irrigated agriculture takes the 70% of the total amount of water collected, so it is the largest user of withdrawn water. Agricultural yields have been improved by the growth of irrigated agriculture and contributed to market stability, making it possible to feed the growing world population. Rapidly rising non-agricultural water demands, shifting food habits, global climate change, and new demands for the development of biofuels are placing increasing pressure on limited water supplies. The rising cost of developing new water, soil erosion, groundwater depletion, the water pollution, the destruction of water-related habitats, and the inefficient use of already existing water sources are the challenges of growing water scarcity for agriculture.
It is projected that the global population will rise to 9.2 billion by 2050, 86% of whom will live in less developed countries and 70% in urban areas. Fifty-three percent of cereal production growth is projected to be met by irrigated agriculture during 2000-2050. In order to meet the rapidly increasing demand for livestock production, especially in Asia, a growing share of these cereals is projected to be used as animal feed. In addition, more affluent diets would contribute to higher demand for more water-intensive crops, such as sugarcane and horticultural crops (Rosegrant et al., 2009).

Even though rice can be cultivated in many water situations, all over the world the best productive results are obtained where continuous controlled submersion is applied. Water, besides meeting the physiological needs of the plant, acts as a thermal flywheel by protecting it from temperature changes, particularly harmful during the critical phases of germination and formation of pollen mother cells. It controls all non aquatic plants and slows down the development of weeds belonging to the Echinochloa species. It keeps the soil in a reduced state, where nitrogen is conserved in the ammoniacal state. In this form, it is available for rice and it avoids washout by binding to the soil.
From this it follows that rice requires a good availability of water for the development of its plant and the governance of water becomes very important for the success of the cultivation (Ferrero et al., 2008, 236-240).
Indeed, in an irrigated lowland system, 1.432 liters of

water are needed to produce 1 kg of rice.
In hard clay soils with shallow groundwater tables, total seasonal water input to rice fields ranges from as little as 400 mm to more than 2.000 mm in coarse-textured (sandy or loamy) soils with deep groundwater tables (IRRI, n.d.).

Water in the rice field is a very important element that characterizes it as a wetland, but its regulation is imposed by the needs of the rice production process. This management, which includes repeated dryings and submersions contributes to create an ecological trap for some species. Consequently, this service provided by rice agroecosystem has a negative effect on an ecosystem service produced by the wetland, namely habitat.

3.2.5
Water purification and waste treatment

The method by which unwanted chemical compounds, organic and inorganic materials, and biological pollutants are extracted from water is water purification. Providing clean drinking water is one of the primary goals of water purification, but it also serves the needs of medical, pharmacological, chemical and industrial applications for clean, potable water. Contaminants such as suspended particles, parasites, bacteria, algae, viruses and fungi decrease with the purification process.
Today, government agencies that set maximum quantities of harmful substances that can be permitted in clean water, usually set the quality of which water needs to be filtered. Multiple methods such as physical, chemical, or biological examination have been developed to test pollution levels, since it is almost impossible to analyze water solely on the basis of appearance.
The levels of organic and inorganic chemicals such as chloride, copper, manganese, sulphate, zinc, microbial pathogens, radioactive materials, dissolved and suspended solids, as well as pH, odor, color and taste are some of the typical parameters evaluated for the assessment of water quality and levels of contamination (Lanfair, n.d.).

The water used in the rice field for the flooding of the

chamber, at the end of the rice season, i.e. at the time of the harvest, is released into the canals and then returns to the river, which in this case is the Po.
The outgoing water is loaded with substances used in cultivation, which endangers the health of the environment.

Therefore, in order to achieve significant improvements in water efficiency in agriculture and, consequently, to increase the availability of water for other uses, particularly for the environment, it is important to apply correct agricultural practices and policy solutions to support them (European Environment Agency, 2012).

In conclusion, wastewater from the paddy field can have a negative impact on the surrounding environment.
In fact, these are closely influenced by the production system used, for example they could contain traces of chemicals, thus putting at risk not only the quality of the water returning to the river but also soil quality and habitat production. Therefore, it can be said that in this case the rice agroecosystem produces a negative effect on the ecosystem.

3.2.6
Disease and pest regulation

Rice fields are managed habitats in which a wide variety of floral, faunal, and microbial organisms provide a broad range of human well-being services. Most of these organisms may not reduce production; many, such as predators, parasitoids, flowering plants, and soil bacteria, are actually beneficial. A few organisms, however, have become pests.
A wide number of insects feed on rice (more than 100). If they occur in the vegetative stage, the rice plant has good compensatory abilities to recover from such injuries.
The relevance of rice insect pests varies from country to country, but most rice-growing areas are affected by planthoppers, particularly brown planthopper, *Nilparvata lugens*; whitebacked planthopper, *Sogatella furcifera*; and small brown planthopper, *Laodelphax striatellus*.
In most rice growing areas, several stem borers and leaf-feeding insects are also present. Stem borer species, such as the yellow stem borer, *Schoenobius incertulas*, and *Chilo supressalis*, the striped stem borer,

may often cause substantial losses in yield. In most tropical and subtropical regions, yellow stem borer is dominant, while striped stem borer occurs particularly in temperate rice.
In the early crop stages, leaf feeders, such as the rice leaf folder, *Cnaphalocrocis me-dinalis*, frequently strike rice, causing highly noticeable leaf damage, but the injury often does not translate into a loss of yield due to plant compensation.
Rice is affected by a wide range of rice diseases, among which blast, sheath blight, bacterial blight, brown spot, and several virus diseases are of main priority, including rice tungro. Rice diseases may be labeled as chronic yield reducers (e.g., brown spot and sheath blight), as with insect pests, while other diseases cause intermittent, usually large-scale, and highly dangerous epidemics.
In all rice-growing areas, a wide range of weeds can be found. For example, 140 species are commonly associated with direct-seeded rice and grasses are a major restriction on rice worldwide, such as the Echinochloa species (Norton & Heong, 2010).

Villareal, S. (2012, March 12). Rice pests multiply post-floods. The New Humanitarian. https://www.thenewhumanitarian.org/feature/2012/03/12/rice-pests-multiply-post-floods

To meet these challenges, and to avoid huge losses in harvest and final profit, farmers must manage pests and weeds, in wetlands they are managed naturally while in rice production process there are many ways to do it. The most traditional techniques are those involving the use of chemicals such as pesticides and herbicides, in organic farming, however, it is not possible to use these

types of products, so pests and weeds are managed with agricultural techniques such as green manure. Anyway, this service is not produced by the wetland itself but is controlled by humans. If pests and weeds are controlled with chemicals, the rice agroecosystem will have a negative impact on the environment.

3.2.7 Soil formation

Soil is the thin material layer covering the surface of the earth and is created by rock weathering. It consists primarily of mineral particles, organic materials, air, water and living organisms, all of which are slowly but constantly interacting.
They are the main source of food for humans, animals and birds, and most plants get their nutrients from the soil.
For their life, therefore, most living things on land depend on soil.
As it is easily destroyed, washed or blown away, soil is a precious resource that needs to be handled carefully. In order to prevent the degradation of one of the basic building blocks of our climate and our food security, it is necessary to understand and properly manage the soil (Queensland Government, 2013).

Soil formation is an ecosystem service provided by the rice field as a wetland, because the particular conditions created by this environment give it certain characteristics.

As a matter of fact, the submerged soil of a rice field is a particular environment with characteristics strongly modified by the conditions of anaerobiosis, linked to the type of irrigation, which differentiate it from most other agricultural soils. Anaerobic conditions show variability in time and space. In time because submergence is normally maintained only during the growing season with some interruptions commonly called “dry”. In space because rice is a biological conductor of air within the soil due to the aeriferous parenchyma that traverse the culm longitudinally. The presence of the crop maintains micro-spaces occupied by air and strongly differentiated from surrounding anaerobic conditions.
Paddy soil stratification consists of four layers.

The first layer is the aerobic water-soil interface, it extends over 5-15 mm and is an oxygenated zone in which oxidized compounds (e.g. nitrates, sulfates or ferric ion (Fe3+) are stable.
The second band is called submerged soil, extending over a depth of 20-40 cm. The conditions of anaerobiosis are established in a few weeks from the submergence and prevail clearly the reducing conditions with transformations at the expense of the various oxidized compounds, visible by the changes in color assumed by the soil and especially due to the different forms of iron (Fe) and manganese (Mn). Afterwards there is the rice rhizosphere which is the portion of submerged soil, but in intimate contact with the rice roots, up to a few tenths of a mm from them. Here the soil regains aerobic conditions for oxygen transport. This zone is particularly active because it is rich in organic carbon derived from root exudates.
The last zone is composed by the subsoil, it extends for a very variable depth, for example up to 1 or 3 m, it is always in anaerobic conditions in its superficial portion, while in the deep one it depends on its permeability and on the groundwater fluctuation regime (Ferrero et al., 2008, 290-291).

3.2.8 Nutrient cycling

Soil has a fundamental role in the cycle of nature, one of its tasks is the nutrient cycle, the ability of soil to absorb and store organic matter such as carbon, nitrogen and phosphorus.
Organisms living in the soil break down organic compounds such as leaves and roots into simpler compounds before they can be used by plants (European Environment Agency, 2019).

In paddy fields the nutrient cycle is altered by the different oxidation-reduction conditions.
The carbon cycle in rice paddies is slowed compared to that of a similar soil under aerobic conditions, but extremely accelerated compared to that measured in a natural wetland.
The increased organic matter content of submerged soil compared to drained soil occurs because the decomposition of organic matter, which is active even under anaerobic conditions, produces much less energy than under aerobic conditions. Consequently, the microbial flora of a submerged soil grows less rapidly than that of a normally drained soil. This indicates that the equilibrium in fixing or making available nutrients to organic matter is slower in rice fields and is achieved over longer periods of time.
In the soil of a flooded paddy field there is a lack of oxygen, therefore, while under oxidizing conditions the nitrogen available to plants is mainly in nitric form (NO_3^-), in a flooded paddy field it is in ammoniacal form (NH_4^+) and, consequently, this is the main nitrogen form absorbed by rice. However, rice is capable of efficiently absorbing nitrate nitrogen if it is available.
Sulfur is present in various oxidation states in the paddy field and its cycle is controlled by microbiological processes; the submerged environment acts predominantly as a sulfur accumulator, which is positive when atmospheric depositions are high. In few cases there are significant emissions of hydrogen sulfide (H_2S) by organic matter, because the presence of ferrous iron (Fe^{2+}) is sufficient to limit such emissions.
Concerning phosphorus, normally after soil submergence the forms of phosphorus available to the crop (soluble in water or weak acid) increase, to reach a maximum between the fourth and the eighth week after submergence, and then decrease again.
Lastly, iron is more abundant than manganese in agricultural soils. Both similarly change their characteristics and consequently those of the soils after submergence. The most obvious effect of submersion is the change in soil color from the reddish color of Fe^{3+} to the grayish-blue color of Fe^{2+} (Ferrero et al., 2008, 293-297).

In conclusion, it must be said that the cultivation process of rice combined with the particular condition of the soil cause the nutrient cycle described above, it creates the right conditions for rice growth but at the same time it produces emission that affects air quality.

3.2.9
Aesthetic values

"Aesthetic value is the value that an object, event, or state of affairs (most paradigmatically an artwork or the natural environment) possesses in virtue of its capacity to elicit pleasure (positive value) or displeasure (negative value) when appreciated or experienced aesthetically. (Plato & Meskin, 2014)"

Giuditta, S. (2019, June 2). Lo specchio della terra: il mare a quadretti delle risaie a Vercelli. Habitante. https://www.habitante.it/habitare/architettura/lo-specchio-della-terra-il-mare-a-quadretti-delle-risaie-a-vercelli/

The rice field is an environment that has an extremely high aesthetic value. Its characteristic chessboard shape is the result of numerous human interventions aimed at upgrading the air to make it cultivable. So, the result is a particular geometric landscape between the artificial and the natural that in the summer season is flooded with water also welcoming numerous species of fauna.(Ferrero et al., 2008, 200-203).

3.2.10
Recreation and ecotourism

L'Ambiente, F. L. P. (2019, November 19). Martin pescatore, infallibile tuffatore. La Rivista Della Natura. https://rivistanatura.com/martin-pescatore-infallibile-tuffatore/

"Ecotourism is defined as responsible travel in natural areas that conserves the environment, supports the well-being of local people, and involves interpretation and education." Education is considered to be inclusive of both workers and visitors.
Ecotourism includes the integration of conservation, communities, and sustainable travel. Any values, such as minimizing the physical, social and behavioral effects, preserving the environment and culture of the area, and creating financial benefits for the local community, must be embraced by people who engage in this form of activity (The International Ecotourism Society, n.d.).

In paddy fields it is possible to carry out ecotourism activities, the characteristic landscape attracts tourists, moreover thanks to the rich birdlife the paddy fields are perfect for birdwatching and other educational activities on the particular practice of rice cultivation.
So, this kind of service is given either from rice field as a wetland but also from agriculture.

3.3 S.W.O.T.

The tool used to analyze the aspects concerning the rice cultivation is the SWOT Analysis, is used mostly in organizations as a tool for strategic management and the result is the creation of a competitive and organizational strategy.
SWOT is an acronym and it stand for: Strengths and Weaknesses, which are internal factors who refer to the company organization, and Opportunities and Threats, which are external factors who refer to external influences on the company. So, internal factors are aspects over which the company has control, while external factors are factors over which the organization has no control.
In particular, strengths include all the positive factors within the company that can help to achieve new goals, as well as the resources and skills possessed.
Weaknesses, on the other hand, should describe the negative factors internal to the company that could negatively affect performance.
Opportunities are those factors from outside the organization that the company could exploit in order to gain an advantage.
Finally, threats are negative factors that affect the company from the outside.
On the basis of what emerges from this analysis it is possible to produce some options that point to improve the business.
The last step of the analysis will be to combine the different categories to develop strategies.
To summarize, SWOT Analysis is a useful tool to use in the initial assessment phase, where it is necessary to have a complete and realistic view of the organization.
It helps to make clear the weaknesses and strengths of the company as well as highlighting the difference between the current position and plans for the future (GÜREL, 2017) (Vlados, 2019) (Benzaghta, Elwalda, Mousa, Rahman, & Erkan, 2021).

In this case, the SWOT analysis has been used to evaluate the rice agro-ecosystem based on the information that has been reported in the previous chapters and paragraphs, from the data concerning the world production, to the cultivation systems used in the Vercelli area, up to the description of the ecosystem services that are present in the rice field (Figure 17).

STRENGHTS

1.Most important food crop

2.Used by about 50% of the population, it represents one fifth of the calories consumed by humans to feed themselves

3.Italy is the first rice producer in Europe

4.Rice grown under a wide range of agroecological conditions

5.From the balance sheet of the Ente Nazionale Risi it can be seen that the internal market is increasing compared to the previous year and exports remain constant

6.In the Italian rice paddies there are about 120 species of birds

WEAKNESSES

1.Diffusion of 100 million tons of methan per year

2.CO_2 emissions due to agricultural machinery

3.When the fields dry the water that submerged them returns to the rivers with traces of chemical substances

4.Soil is contaminated by chemicals

5.A considerable amount of water is used to produce the rice

6. Biological farming is expensive and produces less rice than traditional cultivation

OPPORTUNITIES

1.In rice paddies it is possible to combine several agroecological techniques such as cultivation and breeding

2.New techniques of organic farming, with greater water savings, are spreading in some farms

3.Crop rotation and green manure are two good practices to improve soil quality and fertility without the use of fertilizer

4.False sowing, chain harrow and green mulching help to controll weeds without using chemicals

5.Rice ecosystem can be used for educational purposes with school projects

6.In the rice paddies it is possible to carry out different activities such as birdwatching

7.In the rice paddies it is possible to promote ecotourism thanks to the characteristic landscape and the different activities in contact with nature that can be carried out in the rice fields

THREATS

1.Poor water management can affect the success of cultivation

2.Crop pest could decrease productivity, in the worst case there could be a complete crop loss

3.High levels of CO^2 would cause a reduction in the levels of minerals, proteins and vitamins in rice, reducing its nutritional capacity

4.The repeated dryness after the submersions cause the death of some species that are unable to complete their life cycle, thus leading to the loss of biodiversity

5.Laser levelers remove the possibility of creating temporary wells during dry periods in which some organisms can complete their life cycle, causing their death

Fig.17 The graph represents a diagram of the SWOT analysis of the rice ecosystem, from the left can be found the strengths, opportunities, weaknesses and threats.

#strenghts

Rice is the most important food crop, indeed, about about fifty percent of the world's population eats rice. It also accounts for one-fifth of human calorie intake.
Its extensive use is mainly due to the fact that it is possible to grow rice in a wide range of agro-ecological conditions (Coltura & Cultura, n.d.).
Concerning Italy, it is important to remember it is the first rice producer of Europe, it covers 49% of rice production of the continent (Ente Risi, n.d.).
It is also possible to state that the national market of rice is growing, in fact, the balance sheet of the national rice agency shows that compared to previous years there is a growth, even exports do not fall but remain constant.
Moreover, Italian rice fields are rich in bird fauna, there are about 120 species of birds, 27 species of these are included in Annex I of the Birds Directive, 18 species are attributed to the risk categories of the Italian Red List and 10 species classified as SPEC 2, i.e. with unfavourable European conservation status and populations concentrated in Europe (Regione Piemonte, n.d.).

#opportunities

Among the opportunities there is definitely the use of organic farming techniques, which have less impact on the environment and significant water savings.
There are also good practices that can be adopted such as crop rotation and green manure which can be used instead of fertilizers to improve soil quality.
Then there is the opportunity to use some practices to control weeds while avoiding the use of chemicals, which would be false sowing, harrowing, and mulching.
Moreover, in the rice field it is possible to integrate the traditional cultivation with breeding (Fukuoka, 1985).
This would bring great advantages both from the point of view of profit and from the point of view of the ecosystem (Nayak et al., 2018).
The rice field thanks to its aesthetic value and the richness of fauna offers the possibility of attracting tourism, the large number of species of avifauna present allow activities such as birdwatching or walks and other activities in contact with nature between the chambers of rice field to admire the landscape and the variety of fauna.

The complex cultivation system makes the paddy field interesting also from the educational point of view.

#weaknesses

Weaknesses include methane and nitrous oxide emissions released from the paddy field during the submergence of the chamber (Peyron, et al., 2016).
In addition, in traditional cultivations, the use of chemicals such as fertilizers, pesticides and herbicides have a negative impact as soil and water contamination will occur.
A weakness that comes with the use of organic farming techniques, is the fact that the production of rice will be lower, also some of these techniques such as mulching with film are expensive.

#threats

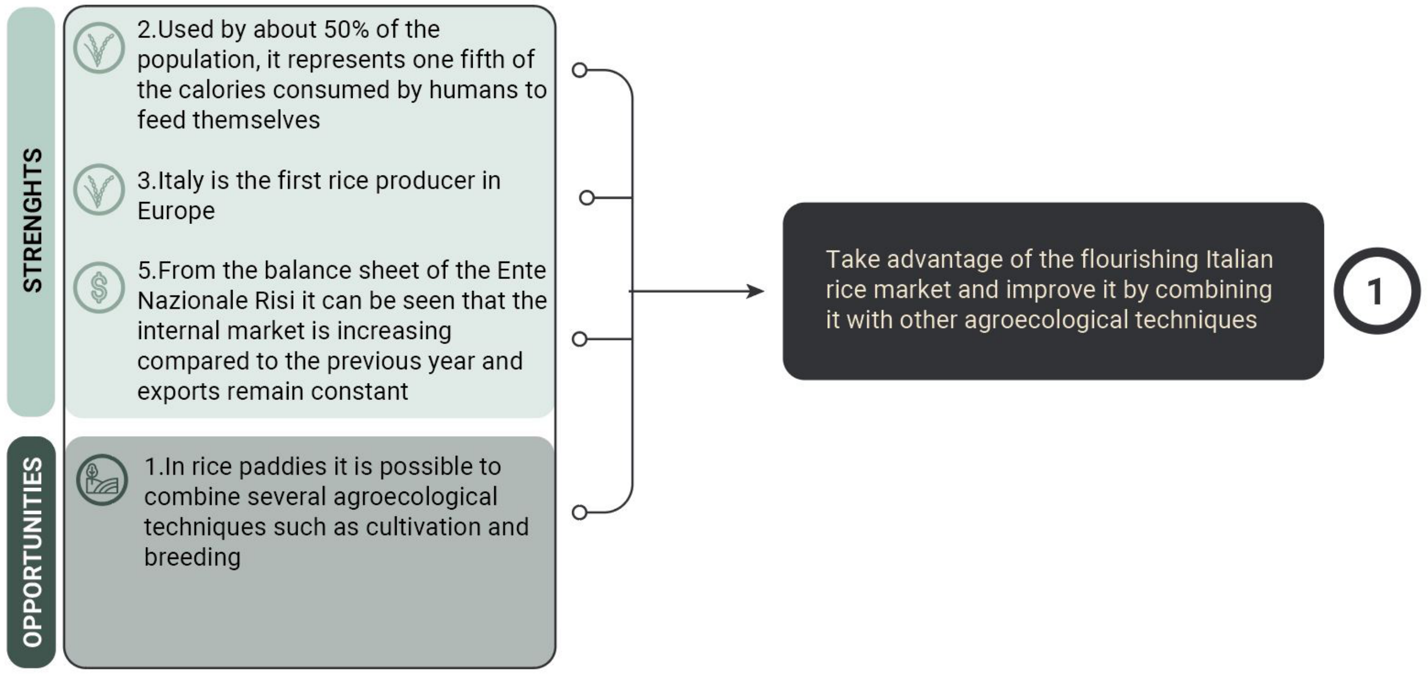
Threats concerning the success of the cultivation are related to a wrong management of water and weeds, which in the worst cases could lead to a total loss of the crop.
Rice quality can be threatened by the use of chemicals to increase production. These types of substances can be harmful to both human health and the environment (Alewu & Nosiri, 2011). The last threats concern the biodiversity that is affected by repeated dry periods, in fact, some species without water are not able to conclude their life cycle, this leads to the proliferation of some insects such as mosquitoes that in this way do not have their predator. Moreover, some new agricultural techniques such as laser leveling, remove the possibility of creating small holes in the soil where some species could conclude their life cycle during the dry periods.

3.4 Strategies

Once all four categories were analyzed point by point, the next step is to connect the different categories of the SWOT by combining the various information together. The purpose is to create possible strategies to improve the paddy ecosystem.
Strategies arise from combining two categories at a time. SO strategies, for example, are the combination of strengths and opportunities, in which opportunities are used to increase strengths. ST strategies, on the other hand, are the combination of strengths and threats, in which strengths are used to limit threats. The third type of strategy is called WO and is the combination of weaknesses and opportunities, in fact here opportunities are exploited to reduce weaknesses. The last category of strategies is WT, which is the combination of weaknesses and threats, in which efforts are made to avoid threats by minimizing weaknesses (Benzaghta, Elwalda, Mousa, Rahman, & Erkan, 2021).

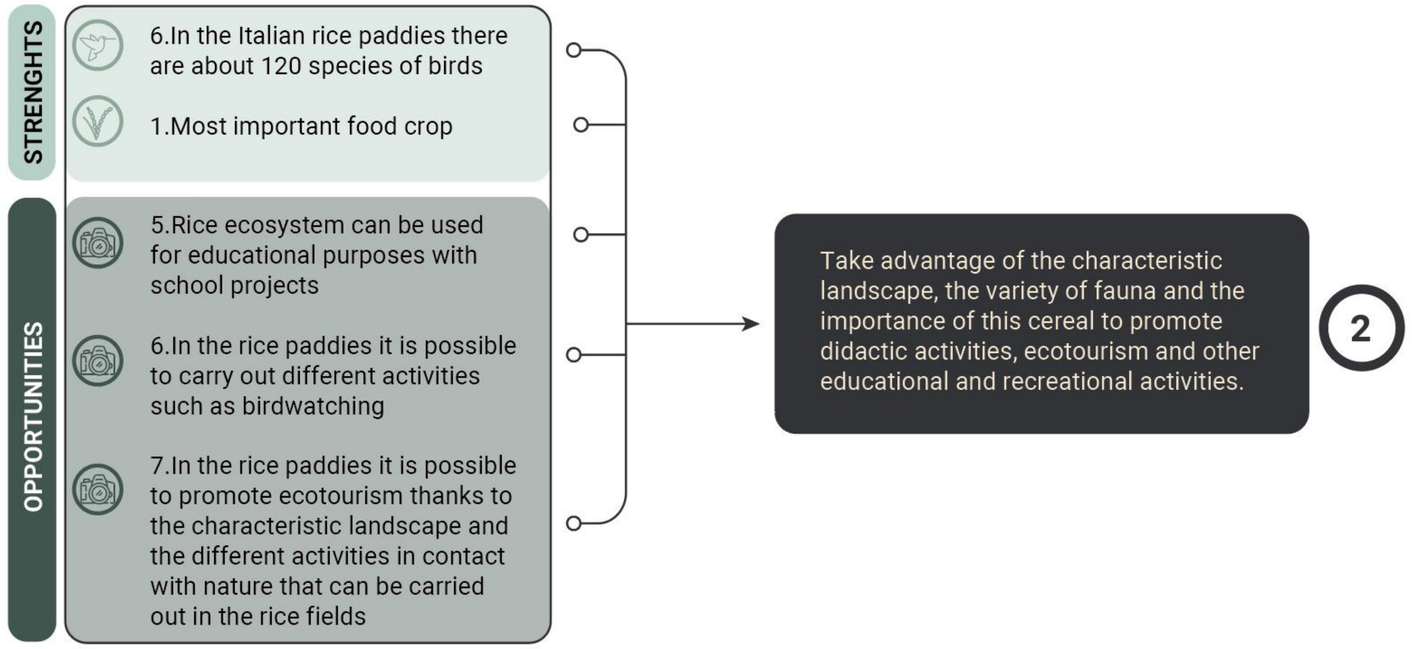
Here have been combined in two ways, strengths were used to take advantage of opportunities (SO) and weaknesses were improved by taking advantage of opportunities (WO).

Fig.18 In the chart, there are a few categories from the SWOT that have been combined to create the first strategy.



For the first strategy (Figure 18), three strengths have been united regarding the performance of the rice market in the world, indeed, the fact that it is consumed by about the 50% of the global population and it is the basis of the diet of many people (it represents one fifth of the calories used by humans to feed themselves), makes it a strong product both in the national market, given that Italy is the leading producer of rice in Europe, and in the international market.
These strengths have been linked to the opportunity to make this product even better through integrated agriculture.
Since the rice market is growing and flourishing in Italy as well, the first strategy proposes to implement it further by integrating other agro-ecological techniques such as breeding with rice cultivation.
Rice-fish-duck integration, for example, exploits optimal ecological niches and transforms them into potential production processes, improving agricultural production, farm income, and soil quality through efficient nutrient recycling in the rice ecology (Nayak et al., 2018).

Fig.19 In the chart, there are a few categories from the SWOT that have been combined to create the second strategy.



The second strategy (Figure 19) proposes to exploit the characteristic rice landscape, which during the summer season is particularly suggestive and the abundance of avifauna present in this ecosystem.
In fact, as mentioned above, the rice fields make up an artificial landscape in a very particular chessboard shape and in summer you can see an immense expanse

of water where more than 120 species of birds live. Activities such as birdwatching or hiking or horseback riding along the banks of the rice paddies can be organized to increase the farm's income. Moreover, some farms organize didactic activities for children in which they are instructed about the cultivation of rice through laboratories in which they can do some work in the agricultural field.
These educational activities in contact with nature, besides bringing a higher profit to the company, are very important to educate all generations to respect the ecosystem and to generate awareness.

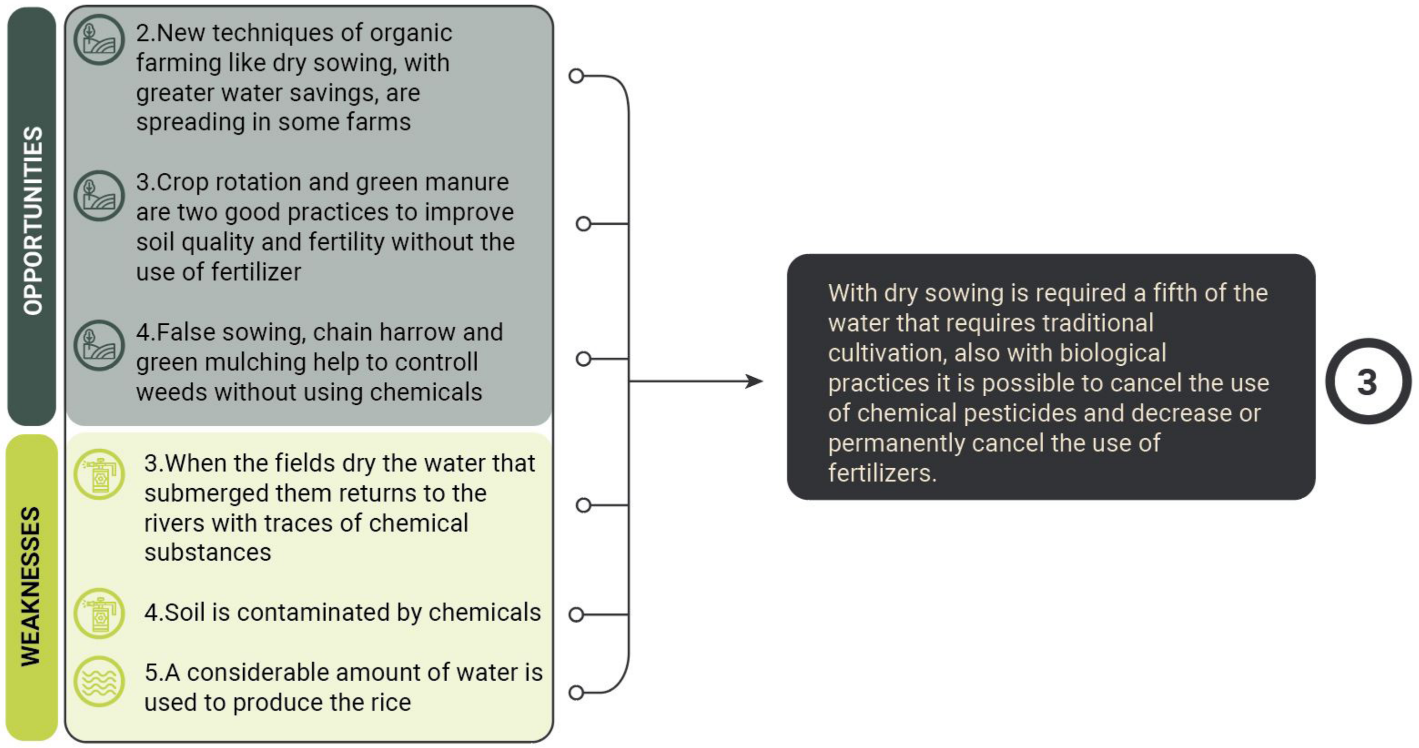


Fig.20 In the chart, there are a few categories from the SWOT that have been combined to create the third strategy.

The third strategy (Figure 20) aims to improve three weaknesses through opportunities.
In traditional rice cultivation techniques, substances such as chemical fertilizers are used to improve soil fertility and pesticides and herbicides are used to combat weeds and pests, thus avoiding partial or even complete loss of the crop.
However, these chemical products have negative effects, by depositing in the soil and in the plant, they influence the nutritional values of the final product, in this case rice.
Moreover, when the rice field is flooded, the chemical products contaminate the stagnant water which, once the season is over, will return, polluted, to the canal and

then to the river.
However, there are techniques used in organic farming that if introduced can avoid the use of these products. For example, crop rotation and green manure which can be used instead of fertilizers to improve soil quality. Then there is the opportunity to use some practices to control weeds while avoiding the use of chemicals, which would be false sowing, harrowing, and mulching. These practices not only respect the environment by not contaminating water, soil and consequently the rice, but also help the company in saving money. As a matter of fact, in this way there will be no expenses for the purchase of fertilizers, pesticides and herbicides.

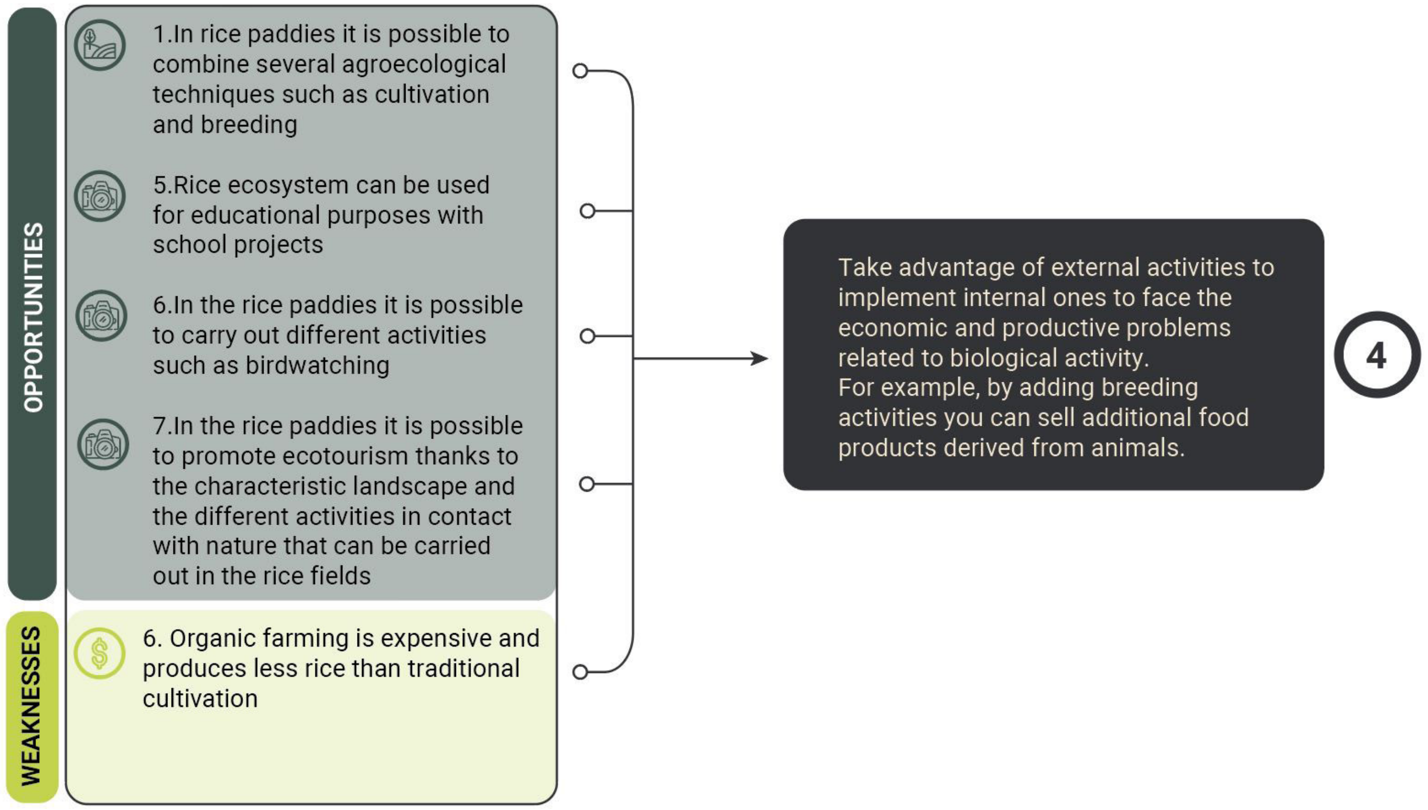


Fig.21 In the chart, there are a few categories from the SWOT that have been combined to create the fourth strategy.

Organic cultivation practices respect the ecosystem and the fauna living in it, these techniques are little invasive and therefore sustainable for the environment.
The main problem of these types of cultivation concern costs, which in case of mulching with film are high, and productivity. In fact, cultivating rice in a biological way means obtaining less harvest per year compared to the production with traditional techniques.
The fourth strategy (Figure 21) tries to cope with this problem by looking for new revenues that can come

from outward activities that the farm can organize, such as educational workshops or promoting ecotourism.
In addition, with regard to productivity, as also mentioned earlier, it is possible to integrate other agro-ecological activities in the paddy field, such as the breeding of ducks and fish, which will also bring new earnings through the sale of new food products.

3.5 Ecological matrix

The matrix is an easy tool to collect and visualize all the data gathered during the scientific analysis that has been done about the different ecosystem services related to the rice paddy ecosystem. In this matrix are provided some categories. On the horizontal axis are represented: Indicators, which are the specific topic of the ecosystem services; description, which are short summaries of the present condition; references, which are resources; proposal, which is the solution to the problems that were identified based on the study of the rice ecosystem. On the vertical axis are the ecosystem services: Supporting, Regulating and Provisioning (Figure 22).

	INDICATOR	DESCRIPTION	REFERENCE	PROPOSAL
REGULATING	air quality regulation	On average, one hectare cultivated with rice emits 3.52 kg of methane (**CH_4**) and 1.17 kg of nitrous oxide (**N_2O**) per year, equivalent to 98% of methane and 6% of nitrous oxide released annually by Piedmont agricultural crops (IREA 2008).	Arpa Piemonte. (2014). Coltivazione del riso. YUAN, W.-, CAO, C.-, LI, C.-, ZHAN, M., CAI, M.-, & WANG, J.-. (2009). Methane and Nitrous Oxide Emissions from Rice-Duck and Rice-Fish Complex Ecosystems and the Evaluation of Their Economic Significance. Agricultural Sciences in China, 8(10), 1246–1255.	A study conducted in the rice paddies of southern China also confirms that **rice-duck and rice-fish** complex ecological planting and breeding models can effectively decrease and control CH_4 and N_2O emissions, and they are two of the effective strategies to reduce greenhouse gases from rice paddy fields and contribute in alleviating global warming.
REGULATING	water regulation	A lot of water is necessary for lowland rice. On average, to produce **1 kg** of rice in an irrigated lowland production system it takes **1,432 liters of water**. Irrigated rice receives an estimated 34-43 percent of the total irrigation water of the world, or about 24-30 percent of the developed fresh water resources of the entire world.	Water management - IRRI Rice Knowledge Bank. (n.d.). Rice Knowledge Bank. Retrieved February 5, 2021 Amin, M. S. M., Rowshon, M. K., & Aimru, W. (2011). Paddy Water Management for Precision Farming of Rice. Current Issues of Water Management, 107–142. SI FA PRESTO A DIRE RISPARMIO IDRICO... (2015, March 13). RisoItaliano | Il Portale Del Riso.	1) By practicing **precision farming** of rice in lowland paddy fields, water savings can be achieved. The system can provide information immediately on the uniformity of the distribution of water and the shortfall or excess, and what decisions to take for the next period. At each crop growth stage, it is possible to determine the required amount of water. 2) An experiment, on the **different methods of irrigation of rice paddies**, evaluate the different water savings. The study shows that irrigation consumption is 20 percent lower with delayed submersion compared to the traditional method, while irrigation needs are reduced by 70 percent with the dry technique. Water savings are achieved by dry underground sowing and delayed submersion in 3a-4 leaves, and even greater savings by turn-irrigation.
REGULATING	deseas and pest regulation	In the paddy field, many insect species grow, but only some of them may become harmful to the crop. The degradation of damaged tissues is caused by this disease. In the most extreme cases, the **reduction in output will exceed 30-40%** .	Ente Risi. (2012, May 30). INSETTI E PATOGENI. Hong-xing, X., Ya-jun, Y., Yan-hui, L., Xu-song, Z., Jun-ce, T., Feng-xiang, L., Qiang, F., & Zhong-xian, L. (2017). Sustainable Management of Rice Insect Pests by Non-Chemical-Insecticide Technologies in China. Rice Science, 24(2), 61–72.	Because of healthy growth by self-regulation, the **co-mutualism combination of planting and breeding ecological system** is a perfect system compared to the conventional rice cropping system. For example, ducks are introduced into the paddy fields in a rice-duck system to increase the pest resistance of rice and reduce rice pests. In the fourth and fifth generations, for instance, rice planthoppers are reduced by 70.2 percent and 70.4 percent in the middle rice season and by 56.2 percent and 64.7 percent in the late rice season, respectively.
REGULATING	water purification and waste tratment	The use of plant protection products carries a possible **risk of surface and groundwater resource pollution**. The presence of these substances in water is often underlined by the findings of periodic testing by regional environmental authorities.	Ferrero, A., Milan, M., Fogliatto, S., De Palo, F., & Vidotto, F. (2016). RUOLO DELLA GESTIONE DELL'ACQUA IN RISAIA NELLA MITIGAZIONE DEL RISCHIO DI CONTAMINAZIONE DELLE ACQUE SUPERFICIALI DA PRODOTTI FITOSANITARI. AIAB Lombardia. (2015, November 4). La pacciamatura verde.	Water contamination can be avoided by eliminating the use of chemicals and using less invasive techniques instead. **Natural mulching** is a process that is gaining more and more popularity due to the many advantages it can offer: hindering the growth of weeds during the summer, decreasing soil evapotranspiration and preserving water for irrigation, shielding the soil from erosion and high temperatures. Mulching degrades and enriches the soil with organic matter once it has accomplished its mission.
PROVISIONING	food	Rice is known internationally to be the grain that has fed the greatest number of individuals over time. Around half of the world's population, and almost the entire Asian population in particular, depends on the nutrition of this food. However, **the quality of this grain is threatened** by the numerous emissions that have a negative effect on the nutritional capacity of rice.	Ferrero, A. (2008). Il riso. Più CO2 in atmosfera, il riso sta diventando meno nutriente. (2018, May 26). Sky TG24. Nuemsi, P. P. K., Tonfack, L. B., Taboula, J. M., Mir, B. A., Mbanga, M. R. B., Ntsefong, G. N., Temegne, C. N., & Youmbi, E. (2018). Cultivation systems using vegetation cover Improves Sustainable Production and Nutritional Quality of New Rice for Africa in the Tropics. Rice Science, 25(5), 286–292.	A study conducted in South Africa on a rice variety called NERICA demonstrates that direct sowing with **vegetation cover systems** on unplowed soil will improve the nutritional quality of rice.
PROVISIONING	habitat	Paddy fields are artificial wetlands that provide food for people and habitat for wildlife and play an important role in agricultural ecological systems. However, **biodiversity is being threatened by new agricultural techniques** that focus on increasing production. Repeated dryness causes the death of some species that are unable to complete their life cycle. Levelers eliminate the possibility of creating temporary ponds during dry periods where some organisms can complete their life cycle, causing their death.	Luo, Y., Fu, H., & Traore, S. (2014). Biodiversity Conservation in Rice Paddies in China: Toward Ecological Sustainability. Sustainability, 6(9), 6107–6124. INTERVENTI A FAVORE DELLA BIODIVERSITA' NELLE RISAIE - LA MISURA 10.1.2 DEL PSR. (2018, March 2). Blog in Campo.	In order to maintain biodiversity in the paddy field, the new programming of the Rural Development Plan has thought about how to mitigate the negative consequences of the practice of dry rice on the biodiversity of the paddy field. The goal is to encourage the **preservation of a reserve of water** during the rice cultivation cycle in order to enable aquatic species to survive even during the dry season and to repopulate the rice chambers during the subsequent flooding phases. Biodiversity protection helps, among other things, to increase the natural control of mosquitoes by facilitating the completion of the biological cycle of their natural predators (the tadpoles, the dragonflies, the fish, etc.), which are severely restricted by repeated dry phases in ordinary conditions.
SUPPORTING	soil formation	Soils that have more than 40% clay in their composition are called clayey and are known as heavy or hard. The workings that are done in this type of soils require **considerable energy** and the extremely small space between the numerous clay particles give a **high water retention capacity, insufficient air presence and poor permeability**.	De Simone, A. (2013, August 28). Terreni argillosi, struttura e caratteristiche. Idee Green. Lu, S.-G., Sun, F.-F., & Zong, Y.-T. (2014). Effect of rice husk biochar and coal fly ash on some physical properties of expansive clayey soil (Vertisol). CATENA, 114, 37–44.	A study on the effects of **rice hush biochar and coal fly ash** on clayey soils, demonstrate that this two substances are able to improve the physical quality, characteristics and swelling-shrinkage status of clayey soils.
SUPPORTING	nutrient cycling	**Nitrogen** is, along with potassium, the plant's most needed nutrient. It has a huge impact on its growth in height, the number of culms, the filling of the grains and, eventually, the productivity of the crop. In order to increase resistance to plant diseases and enhance grain quality, **potassium** is essential. Particular importance is given to the **organic substance** present in the soil or integrated with fertilizers in order to increase the agronomic performance of fertilization. Organic fertilization increases in significance in looser soils, where the capacity to maintain nutrients is lower.	L'IMPORTANZA DI UNA CONCIMAZIONE RAZIONALE DELLA RISAIA. (2003, November 25). AgroNotizie. Sovescio. (n.d.). Ristec. Retrieved February 4, 2021	**Green manure**'s primary purpose is to provide the rice with nutrients, but also to increase soil fertility. The use of leguminous plants, as nitrogen fixers, also makes it possible to supply the system with atmospheric nitrogen. In general, the vetch, whose nitrogen inputs range from 40 to 140 kg/ha, is a species of leguminous plant suitable for the Italian climate and rice systems.
CULTURAL	aesthetic values	The peculiarity of the rice landscape is given by its characteristic chessboard composition. It is a **natural landscape** but at the same time **artificial** because it has been modified by man.	Ferrero, A. (2008). Il riso. PSR 2014-2020 of Piedmont and Lombardy	For the care of the rice environment, the Piedmont region allocates funds for some **good practices** to maintain biodiversity and consequently add aesthetic value to rice fields. For example, the maintenance of vegetation in at least one chamber embankment that is typically combined with the construction of a ditch.
CULTURAL	recreation and ecoturism	Recreational activities and tourism in rice fields are mainly due to the richness of avifauna. A study in Japan revealed that some insecticides and their derivatives were detected at high concentrations in aquatic areas around paddy fields, especially in sediment samples. These findings pose big questions about the **ecological risks** to aquatic ecosystems which in turn influences the presence of the numerous bird species.	Furihata, S., Kasai, A., Hidaka, K., Ikegami, M., Ohnishi, H., & Goka, K. (2019). Ecological risks of insecticide contamination in water and sediment around off-farm irrigated rice paddy fields. Environmental Pollution, 251, 628–638. Dermiyati, & Niswati, A. (2014). Improving Biodiversity in Rice Paddy Fields to Promote Land Sustainability. Sustainable Living with Environmental Risks, 45–55.	In order to eliminate the use of substances that endanger biodiversity, improvements are necessary, one solution may be to change the type of **cultivation** from traditional to **biological**. This means using organic products or completely eliminating their use through alternative techniques.

Fig.22 The chart represent the Ecological Matrix, on the horizontal axis are represented: indicators, which are the specific topic of the ecosystem services; description, which are short summaries of the present condition; references, which are resources; proposal, which is the solution to the problems that were identified based on the study of rice ecosystem.

3.5.1
Air quality regulation

#problem

Rice is cultivated for 75% in submergence in Italy, as this element has a thermoregulating function.
However, this condition causes methane emissions due to the anaerobic condition caused by the submerged environment.
In addition, there is the emission of nitrous oxide due to microbial nitrification and denitrification in the soil. This condition is intensified by the use of nitrogenous fertilizers.
The typical technique used to cultivate rice, makes the sector of this cereal one of the most greenhouse gas emitting sectors together with animal husbandry.
Corinair's methodology has proven that one hectare cultivated with rice emits an average of 3.52 kg of methane and 1.17 kg of nitrous oxide per year, which would be the 98% of the methane and 6% of the nitrous oxide released annually from Piedmontese agricultural crops.
It should be noted, however, that the impact of these two elements is different, if considered in equal quantities, methane has an effect 28 times greater than carbon dioxide on climate, while nitrous oxide up to 300 times greater (Arpa Piemonte, 2017) (Arpa Piemonte, 2014).

#possible solution

An experiment conducted in Wuhan, China, shows that by integrating ducks and fish into rice farming, it is possible to control CH_4 and N_2O emissions.
A field of 1.260 m2 was divided into 3 parts in which three different treatments were made.
In one, 300 ducks per hectare were introduced (called RD), in the second, 15.000 fish per hectare were introduced (called RF) and the third was traditionally cultivated with rice only (called CK).
The research conducted by the paper, shows some results about CH_4 emission during rice season and affirms that: in 2007, during ducks rearing or fish introduction, CH_4 emission fluxes from RD and RF were, respectively, 74% and 88% of that from CK in 2006. Total CH_4 emissions fluxes from RD and RF were respectively 77% and 82% of that from CK in 2007.
Then also some results about N_2O emission are shown: in 2007 during duck rearing or fish introduction, N_2O fluxes from RD and RF were respectively 130% and 93% than that from CK in 2006.
To summarize, the results show that CH_4 emissions in fields where ducks and fish have been introduced peak at the full tillering stage and heading stage, however on average the fluxes are significantly lower than in the field where only rice is grown.
Compared to the field where only rice was grown, the total amount of N_2O emissions were significantly higher and slightly lower than those where ducks and fish were introduced, respectively (YUAN et al., 2009).

Menezes, F. (2019). Ducks, not pesticides! An ancient Chinese farming method is catching on with farmers worldwide. Brightvibes. https://brightvibes.com/932/en/ducks-not-pesticides-an-ancient-chinese-farming-method-is-catching-on-with-farmers-worldwide

3.5.2
Water regulation

#problem

As already explained in previous pages, the water in rice fields has a fundamental role which is that of thermal flywheel.
For this reason in general paddy fields are flooded and remain in this state until seven or ten days before harvesting.
On average in a lowland cultivation system to produce one kilogram of rice, 1.432 liters of water are needed.
When water from irrigation and rainwater are combined, the total water used in the rice season can range from 400 mm if rice has grown in clay soils, to more than 2000 in sandy soils.
Rice crops that receive water through irrigation use about 34-43% of the total amount of water used for irrigation in the world.
For what concerns the freshwater resource in the world, about 24-30% of it is used for growing this cereal.
The availability of water for agriculture is more and more scarce, therefore it is necessary to take some measures and manage it in the most proper way (IRRI, n.d.).

#possible solution

In order to best manage water in a rice field, there are three main things to consider.
The first involves channeling water in and out of the chambers so that each farmer has control over it.
Channels are particularly useful when it is time to dry the field before harvesting.
Another important action is to fill in the cracks due to water drainage, to do this it is necessary to plow the soil or even puddling the field.
However, this last operation may not be effective for sandy soils and heavy clay soils.
The third step necessary for good water resource management is to level the soil before sowing.
Soil that is not properly leveled may require an additional 80 to 100 mm of water to meet the needs of the crop (IRRI, n.d.).

A study conducted on a rice crop in Malaysia examined water management in the paddy field.
After collecting data on climate, water demand, etc. for several years, a precision farming system called GIS was developed.
As the season progresses, the device offers valuable information on the actual field situation with regard to water demand and helps to assign the correct amount of irrigation supplies for the next day or time (Amin et al., 2011).

An experimentation in which different irrigation methods were compared in order to evaluate the possible water saving, shows some data regarding the use of water in rice fields.
The results show that with delayed submergence there is a 20% lower water consumption compared to the traditional cultivation technique. With the dry system there is a saving of 70%.
Savings are also obtained by using the technique of sowing in dry and submergence in the third / fourth leaf, with the turn irrigation the water saving is even greater (SI FA PRESTO A DIRE RISPARMIO IDRICO..., 2015).

3.5.3
Disease and pest regulation

#problem

Several species of insects proliferate in the rice ecosystem, some of them are not harmful while others can affect rice cultivation.
For example, the Rice Water Weevil (*Lissorhoptrus oryzophilus*) appeared in Italy in 2004, probably arrived accidentally together with damaged goods at the airport of Milan. This pest is considered the most dangerous for rice at international level.
There are also some species of aphids which can be carriers of the virosis called Yellowness.
The most damages to rice cultivations are however due to a fungal disease known as Brusone (*Pyricularia grisea*).
The Brusone causes the destruction of tissues and only because of this disease the production can decrease up to 30-40%.
There are also other diseases which can be found in lesser percentage such as Elmintosporiosis, Fusairosis and Rice Yellowness (Ente Risi, 2012).

#possible solution

For animal and plant pest control, chemicals have always played a key role.
However, the use of these products has negative effects on the ecosystem, putting biodiversity and agricultural sustainability at risk.
There is also the danger of reducing the quality of the rice produced.
A study conducted in 2017 in China, proposes several solutions to combat pests without the use of chemicals.
A sustainable solution is to carry out field modifications to conserve natural enemies.
The study states that implementing a green manure after the rice harvest with chinese milk vetch (*Astragalus sinicus*) can provide natural pest control.
A high number of species and diversity index of arthropod natural enemies was recorded.
For natural wintering enemies, the milk vetch fields offered favorable conditions where natural enemies accounted for 67,9% of the total insect species.
Another strategy for sustainable pest control is that of integrated agriculture.
Because of the healthy development by self-regulation, the co-mutualism combination of planting and breeding ecological systems, such as rice-duck, rice-fish, rice-soft shelled turtle and rice-crab, is a perfect system compared to the conventional rice cropping system.
For example, introducing ducks into the rice crop increases disease resistance and reduces pests.
It was shown that planthoppers decreased by 70,2% -70,4% in the middle of the rice season and towards the end by 56,2%-64,7%.
In addition, a good result was obtained for the control of Striped stem borer (*Chilo Suppressalis*). The damage produced by this pest was reduced by 13,4%-47,1% in the middle of the rice season and toward the end by 62,2% (Hong-xing et al., 2017).

3.5.4
Water purification and waste treatment

#problem

The use of chemicals creates the risk of water contamination.
The authorities that carry out periodical controls for the presence of these substances in water resources have highlighted that phytosanitary products and herbicides are those that are most detected.
In the agricultural context of paddy field the risk of contamination is particularly high, given the great presence of water bodies.
In these contexts sometimes phytosanitary treatments are made with flooded chambers.
In Italy, the areas where the highest contamination is recorded are Lombardy and Piedmont, regions from which most of the Italian rice production comes from.
The most critical aspect in rice field concerns the execution of treatments both with the submerged chamber and dry but saturated with water. In the first case the contamination occurs directly, while in the second case it occurs when the paddy is submerged again after the treatment.
In both cases there is contamination in the water that after cultivation flows back into the drainage ditches and then into the network of canals (Ferrero et al., 2016).

#possible solution

Sustainable weed control practices are necessary to avoid water contamination.
Mulching is a possible solution for natural weed control, plus it brings many benefits such as saving water and protecting the soil from high temperatures, as well as providing additional organic matter once degraded.
A study conducted in the USA by researchers at the Rodale Institute shows that rye is the ideal cover crop for good weed suppression, allowing crops to be cultivated with minimal work, even if it requires supplemental fertilization.
The best cover crop for nitrogen fixation is vetch, but it is not optimal for weed control and yield.
With a combination of the two cover crops it is possible to obtain a cover that provides both benefits, this combination offers the highest yield, the best weed control and provides the adequate amount of nitrogen (AIAB Lombardia, 2015).

3.5.5
Food

#problem

As we already said in the previous chapters rice is known internationally to be the grain that has fed the greatest number of individuals over time. Around half of the world's population, and almost the entire Asian population in particular, depends on the nutrition of this food.
However, a study shows that carbon dioxide in the air reduces the nutritional capacity of rice.
In fact, it seems that high levels of CO_2 cause a reduction in the rates of minerals, proteins and vitamins.
Eighteen types of rice grown under conditions of high CO_2 concentration were analyzed, and the nutrient content was lower in all species.
On average, 10 percent protein, 8 percent iron and 5 percent zinc were lost in each form of rice. As much as 30 percent lower was the levels of certain B vitamins (Più CO_2 in atmosfera, il riso sta diventando meno nutriente, 2018).

#possible solution

A study conducted in Africa on two rice varieties (Nerica 3 and Nerica 8) grown in a soil with low nutrient content, compares different cultivation techniques to verify rice quality.
The four cultivation systems used are as follows: plowing, unplowed soil with dead vegetation cover, unplowed soil with live vegetation cover and unplowed soil with mixed vegetation cover.
The cropping systems unplowed soil with dead vegetation cover and unplowed soil with mixed vegetation cover increase the total amount of protein by 84.8% and 75% higher than traditional cultivation in Nerica 3 variety.
Soluble carbohydrate levels in the Nerica 8 variety also increased by 73.2% and 57.3% due to the unplowed soil with live vegetation cover and unplowed soil with mixed vegetation cover cropping systems.
These findings indicated that the nutritional efficiency of rainfed Nerica could be improved by a conservative approach such as direct sowing on unplowed soil with vegetation cover systems (Nuemsi et al., 2018).

3.5.6
Habitat

#problem

In addition to being a source of food for humans, rice paddies provide habitat for wildlife.
The biodiversity that develops in rice fields, helps to maintain ecosystem stability and is part of the ecosystem services that provides the paddy field, thus participating in creating economic value for society.
The modernization of agriculture to increase production and therefore profit has put at risk animals and plants that were once common in rice fields, causing a loss of habitat for many species.
One of the causes of this loss of biodiversity is new water management techniques.
Since the 1990s, researchers have developed and tested various water-saving techniques such as dry farming or turn irrigation.
These new techniques inevitably modify the ecological environment of the rice field, in fact especially the aquatic species are affected by these new conditions.
The vital cycle of some species is long and repeated droughts do not allow its conclusion.
In addition, to make irrigation efficient, agricultural techniques such as laser leveling have been adopted to ensure that no small pools of water are created in the field.
Those puddles that formed in the fields, however, were useful for biodiversity purposes for the development of certain aquatic organisms.
Another innovation that puts a strain on biodiversity is the use of chemicals for weed control.
These products have contributed to the development of today's agriculture, but their disproportionate use greatly damages the natural environment and wildlife.
The habitats of the Paddy field are extremely fragile, and the depletion of biodiversity of the rice paddy ultimately disturbs the ecological balance, impacting the biological population.
Pesticide-sensitive natural enemies, especially parasitic natural enemies that are biochemically or morphologically similar to insect pests, are easily affected by the use of pesticides, whereas insect pests may easily establish resistance to pesticides.
Changes in the weed population resulting from the use

of herbicides indicate successive behavior; long-term chemical use will regulate the target weed effectively, but will enable the emergence of non-target species as major weeds (Luo et al., 2014).

Fauna delle risaie. (n.d.). Ferrara Terra e Acqua. Retrieved February 24, 2021, from https://www.ferraraterraeacqua.it/it/scopri-il-territorio/itinerari-e-visite/itinerari-enogastronomici/la-terra-del-riso/photogallery-terra-del-riso/fauna-delle-risaie/view

#possible solution

Rice should be cultivated with the submergence technique, in order to sustain the conservation of the species that inhabit the wetlands that characterize the rice agroecosystem.
Submersion, in fact, is the added value of rice fields for biodiversity.
For the periods in which the paddy field is in dry conditions, when the technique of submersion is used, the impact can be limited by the creation of permanent water reserves within the paddy field chamber.

For example, the excavation of a ditch placed along the edges of the paddy field can provide shelter for amphibian tadpoles, fish, insect larvae, and other aquatic invertebrates. Once submerged conditions are restored these organisms can once again repopulate the entire surface of the paddy field chamber.
As a result of this solution, the paddy field provides a feeding and refuge site for waterfowl, especially in spring and summer.
Another positive effect is the reduction of mosquito larvae due to the increase of their natural predators.
Regarding this intervention, which is the creation of a permanent water basin, in the Piedmont region it is possible to adhere for five years to the measure 10.1.02 of the RDP 2014-2020 (still in force).
This measure provides as a basic commitment the construction of a 60x40 cm furrow at least 100 m long with an expense reimbursement of 125 €/ha/year and as an accessory commitment the digging of a 100x80 cm furrow of the same minimum length with an expense reimbursement of 250 €/ha/year (Giuliano et al., 2017).

3.5.7 Soil formation

#problem

The soils of Vercelli's rice fields are mostly clayey.
This type of soil is very fertile, has a plastic consistency to the touch and maintains the shape it is given.
Clayey soils are also called heavy or compact and are composed of more than 40% clay.
Related to the structure of this soil, however, there are some negative aspects to consider.
As a matter of fact, clayey soils, by retaining humidity, present difficulties in drainage and in order to improve structure it needs a lot of manpower with the addition of compost and organic fertilizers.
The operations which generally must be done for the preparation of this soil are: ploughing, in order to improve the overall porosity and the degree of compactness of the soil; harrowing in the sowing period above all; weeding and amendments if it is necessary (De Simone, 2013).

#possible solution

A 2014 study evaluated the effects of rice husk biochar and coal fly ash on the aggregate formation and stability, distribution of pore size, water retention, swell-shrinkage, limit of consistency, and tensile strength of an expansive clayey soil.
These two substances were then placed in the soil at four levels and subsequently incubated for 180 days.
The results of the research showed that rice husk biochar significantly increases macroaggregates with a diameter larger than 0.25 mm and reduces microaggregates with a diameter of < 0.25 mm.
Furthermore the rice husk biochar amended soil has higher water-holding capacity and higher water content available.
Pore size distribution calculated by mercury intrusion porosimetry of rice husk biochar and coal fly ash amended soils indicates that the amendment increases the development of mesopores with a pore size range between 6 and 45 μm. The modified soils are observed to have considerably higher porosity in the measured pore range (0.003–360 μm).
By binding microaggregates together to form macroaggregates and mixing carbon and fly ash particles with clay mineral phases to form a larger complex, the rice husk biochar and coal fly ash influence the pore size distribution of clayey soil.
Rice husk biochar and coal fly ash application decreased the plasticity index, swelling potential and tensile strength of clay soils, resulting in less energy to break soil clods. Application of the rice husk biochar and coal fly ash can therefore effectively solve the issue of the formation of clods in clayey soil.
In conclusion, this study showed that rice husk biochar and coal fly ash are capable of substantially improving aggregate stability, reducing coefficient of linear extensibility and tensile strength, and improving a variety of other physical properties. In addition, for the enhancement of clayey soils, the rice husk biochar and coal fly ash are good soil amendment agents (Lu et al., 2014).

3.5.8
Nutrient cycling

#problem

The nutrient most required by the rice plant is nitrogen, as it is the element which conditions its development in submersion.
It influences the growth in height of the seedling, the number of tillering culms and in general the productivity.
A deficiency of this element would penalize the crop.
The other element of fundamental importance together with nitrogen is potassium. It plays a fundamental role in developing resistance to plant diseases and in improving grain quality.
Potassium reserves can be depleted by percolation of flood water.
Organic matter is also of particular importance, as it helps improve agronomic fertilization efficiency.
Looser soils have poor nutrient holding capacity, so organic fertilization becomes vital in these types of soils.
A less important element is instead phosphorus, useful for the development of the root system and to improve resistance to cold mainly in the first phases of development. In any case, soils cultivated with rice are usually well provided with this element (L'IMPORTANZA DI UNA CONCIMAZIONE RAZIONALE DELLA RISAIA, 2003).
Generally, the supply of these nutrients is done with the use of chemical products in traditionally cultivated fields and as we have seen in the previous paragraphs, they can contaminate water and environment.

#possible solution

The technique of green manure allows to obtain excellent results both from an agronomic and environmental point of view.
The main function of this technique is to provide nutritive elements to rice and contribute to the improvement of soil fertility.
Generally, in the rice areas of Italy, vetch is used as a winter crop because it is more suited to the climate of the area.
The contributions of nitrogen given by this species are from 40 to 140 kg/ha.

Thanks to the nutritive elements brought by green manure it is possible to substantially reduce, if not completely eliminate, the use of fertilizer (Ristec, n.d.).

3.5.9
Aesthetic values

#problem

As mentioned before, the aesthetic value of rice fields is due to their characteristic natural but at the same time artificial landscape.
This value is also due, however, to the presence of various species of birds, the green of the submerged plants, the water that floods the chambers in the summer season and the rows of trees and vegetation that divides the fields one from the other (Ferrero et al., 2008, 200-203).
All these peculiarities that make the paddy field an ecosystem with a high aesthetic value, are threatened by intensive production systems that aim to increase productivity and profits.
For example, as seen in previous paragraphs, biodiversity is put at risk by new techniques of water management and the use of chemicals.
In addition, water management techniques that aim to save water such as dry cultivation or rotational irrigation would make the flooded landscape enjoyable only for a very short time, thus losing the main characteristic of rice fields.

#possible solution

The University of Pavia in collaboration with Lipu Birdlife Italia, Unilever and Parboriz SpA have developed a project called Biodiversity Action Plan.
In this document actions have been proposed following experiments and consultations of scientific literature to improve the quality of the environment.
Among the best practices there is the maintenance of a permanent water reserve inside the paddy field chamber that, as explained in the paragraph concerning the habitat, is a good way to protect biodiversity. As well as the creation of semi-natural non-cultivated areas that would provide a refuge for organisms present in the paddy field especially during agricultural work. In addition, the project supports continuous submergence

Trisorio, A. (2020). Ambiente, contrastare la perdita di biodiversitÃ e sostenere servizi ecosistemici, habitat e paesaggio? La situazione italiana. Pianeta PSR. http://www.pianetapsr.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/2362

cultivation.
Another measure that can be adopted to restore environmental heterogeneity in the rice environment is a proper management of the banks.
Such as planting or maintaining shrub hedges and rows of trees along the fields using native essences.
However, it is important that these changes do not hinder agronomic activities (Giuliano et al., 2017).

3.5.10
Recreation and ecotourism

#problem

Rice culture has very ancient origins, probably dating back to 10.000 years ago in the Himalayas, only to arrive in Italy and in Vercelli during the Renaissance (Strada Del Riso Vercellese, n.d.).
The cultivation of rice has therefore a long tradition and is made even more particular by the unique management of water.
Talking specifically about the province of Vercelli, the

rice fields of this place are surrounded by culture and places of interest as it is written in an article of Corriere in the travel section.

“(…) merita una visita l’abbazia benedettina di San Nazzaro, per poi sconfinare in provincia di Vercelli, arrivare nel Parco naturale delle Lame del Sesia e scendere verso il capoluogo. Vale una sosta la Cascina dei Fiori di Borgo Vercelli, dove il leitmotiv del territorio (riso, borlotti e, in estate, persino le rane) è ben evidente sulla tavola dello chef Massimo Milan. Un ultimo sguardo aperto sulla pianura e sul Monte Rosa all’orizzonte, per poi entrare in città e farsi catturare la vista dall’imponente basilica di Sant’Andrea, dove un gotico precoce si è imposto su elementi romanici. Da visitare anche il Museo Borgogna, che, accanto a opere di Tiziano, Palma il Vecchio, Ghirlandaio e Bruegel, custodisce Per ottanta centesimi (1895), opera del divisionista Angelo Morbelli. Il titolo allude proprio alla paga giornaliera delle mondine, chine, al lavoro nell’acqua. Dall’arte alla realtà, ci si rituffa in risaia andando verso Trino. A Desana s’incontra la Tenuta Castello , dove dormire nelle otto camere ricavate dalle scuderie e intitolate alla differenti varietà coltivate. Al nome scientifico del riso rende, invece, omaggio Oryza, il ristorante risotteria, con annesso store. Spostandosi a est, si punta al Principato di Lucedio: qui i monaci cistercensi fondarono l’abbazia nel 1123 e impiantarono il riso importato dalla Cina, dando il via alla vocazione risicola del vercellese. Un ritorno alle origini, per una scenografica conclusione del tour tra le terre d’acqua. (Mollica, 2019)”

The possibilities offered by the rice environment and its surroundings are often not properly exploited. In fact there are few farms that organize educational and recreational activities to involve people in their work.

#possible solution

The activities that can be carried out in the rice field are numerous and various, from sports to educational ones. The association Parco delle Risaie Onlus in collaboration with Connecting Cultures and the Municipality of Milan, has developed a project for the requalification of the Parco delle Risaie with the aim of enhancing and promoting the open spaces with agricultural connotation of the city of Milan so that they can provide some services to the city and enhance the tradition of rice production in Milan to focus on the role of the farmer in territorial culture.
One of the proposed activities is the creation of two paths in which visitors, equipped with digital media, will be able to see and touch the phases of cultivation with an explanation of the more technical aspects such as water management and flora and fauna.
It was also proposed to organize events such as shows, demonstrations, exhibitions and concerts using the resources of the place.
Another proposal was to organize a didactic agricultural center where rice is grown and farm animals are bred with the aim of educating school children about rural life.
Linked to this, it is also possible to organize internships in the agro-environmental and food-gastronomic fields.
In addition to social and cultural activities, sports activities such as biking, jogging or even simple walks in the countryside are also proposed (Associazione Parco Delle Risaie Onlus, Connecting Cultures, & Comune di Milano, 2010).

Fattoria didattica: vieni a scoprire il mondo de Le Barbarighe! (2017, June 1). Le Barbarighe. http://lebarbarighe.it/fattoria-didattica-vieni-scoprire-mondo-de-le-barbarighe/

Case study

Photo by Chema Photo on Unsplash

The second part of this thesis concerns the in-depth investigation of a case study.
A farm in the Vercelli area was analyzed and, thanks to an interview organized with the owner of the farm, quantitative data concerning it were collected.
Then, the cultivation techniques used by the farm were analyzed and on the basis of all the information obtained, a SWOT Analysis was carried out from which some possible strategies emerged.
After choosing the strategy to be pursued and after considering the positive and negative aspects concerning it, the linear management system of the paddy field was transformed into a systemic one.

Photo by Al Soot on Unsplash

4.0 Priorato farm

Priorato farm is a company which cultivates rice. The current management of the rice field began four years ago. While in the past, until about 50 years ago, there was a monoculture of rice and rice was grown in the traditional way, today the current manager cultivates about half of the fields with the biological technique of green mulching.

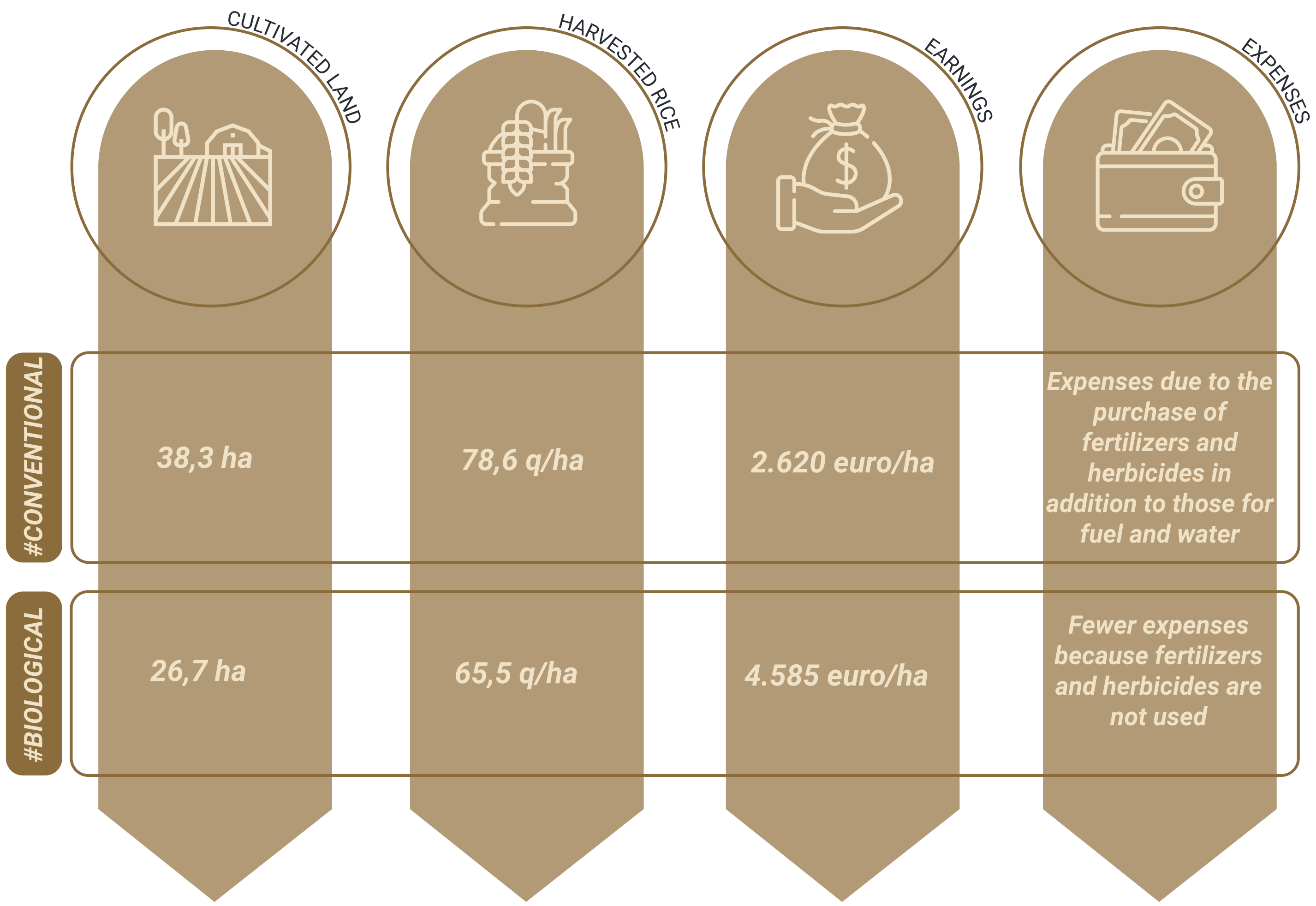
The company is also part of an association called Polyculturae, which is committed to the use of agricultural techniques that respect the rice environment and its biodiversity.
“La aziende agricole fondatrici e tutte quelle che vorranno aderire, sono e saranno uniti dalla volontà, che poi è il fine statutario di Polyculturae, di promuovere tra gli agricoltori, ma anche nella Comunità Scientifica e nella popolazione, lo studio, la diffusione e l’attuazione pratica del recupero, del rispetto e della tutela della Biodiversità in generale e, in particolare, degli Agro-Ecosistemi.”
Polyculturae association has developed a collective brand for all the companies which preserve agro-biodiversity through concrete actions and agronomic techniques.
The brand is called Biodiversitas and its aims are to obtain a high level of biodiversity from companies that already have a biological cultivation and to spread awareness to consumers about respect and protection of the natural environment. (Polyculturae, 2019)

4.1 Rice cultivation methods

After having an interview with the Priorato owner, it was possible to collect some data about the farm (Figure 23).
The land is cultivated with two different techniques, as a matter of fact 38,3 ha are cultivated traditionally (sowing in water and permanent submersion), whereas 26,7 ha are cultivated biologically (green mulching).
With this last technique 65,5 q/ha of rice are produced and the revenue is 4.585 €/ha. By contrast with the traditional technique (38,3 ha) 78,6 q/ha of rice are harvested with the revenue of 2.620 €/ha.

Fig.23 The graph represents a scheme of the farm data collected with interview

The fields cultivated by the company are very fertile and the rice grows in optimal conditions in terms of soil and water.
In fact, the farm can produce twice as much rice as farms in the Baraggia region, for example.



4.1.1 The conventional technique: sowing in water and permanent submersion

The cultivation of the field with this technique (Figure 24) starts with the construction of banks and the field preparation with plough, chain harrow and the laser leveller. Then the first treatment with fertilizer (mineral manure) and herbicide is applied in the paddy field.
In May, the paddy field is flooded and then the rice is sown. During the summer, two more treatments with fertilizer and herbicide are made (one in June and the other in July), before which it is necessary to dry the paddy field which, however, is flooded again soon after. Harvesting takes place in October, before which the paddy field is permanently dried.
All input products are purchased from a local agriculture store called Balzaretti agri-business. For each fertilization treatment, 520 kg of NPK and 130 kg of Urea are used. For the first herbicide treatment that occurs in May, before planting, 2.5 l of RoundUp is used. For the second and third, 1 l of Aura, 1 l of Dash and 2 l of MCPA are used.
This type of cultivation turns out to be harmful for several reasons. In addition to methane and nitrous oxide emissions due to rice cultivation, there will also be emissions due to the constant and intense use of agricultural vehicles.
The techniques used for soil preparation damage biodiversity because the precision of new technologies will no longer make available temporary pools of water in the field that allowed some individuals to survive. Biodiversity in this scenario is also put at risk by the repeated drying and the use of chemicals for soil fertilization and herbicide treatments.
The latter also create problems of contamination in the soil and water leaving the paddy field chamber.
Destroying the habitat of animal species that should populate the paddy fields will trigger chain effects that also have an impact on economic and recreational activities of man.

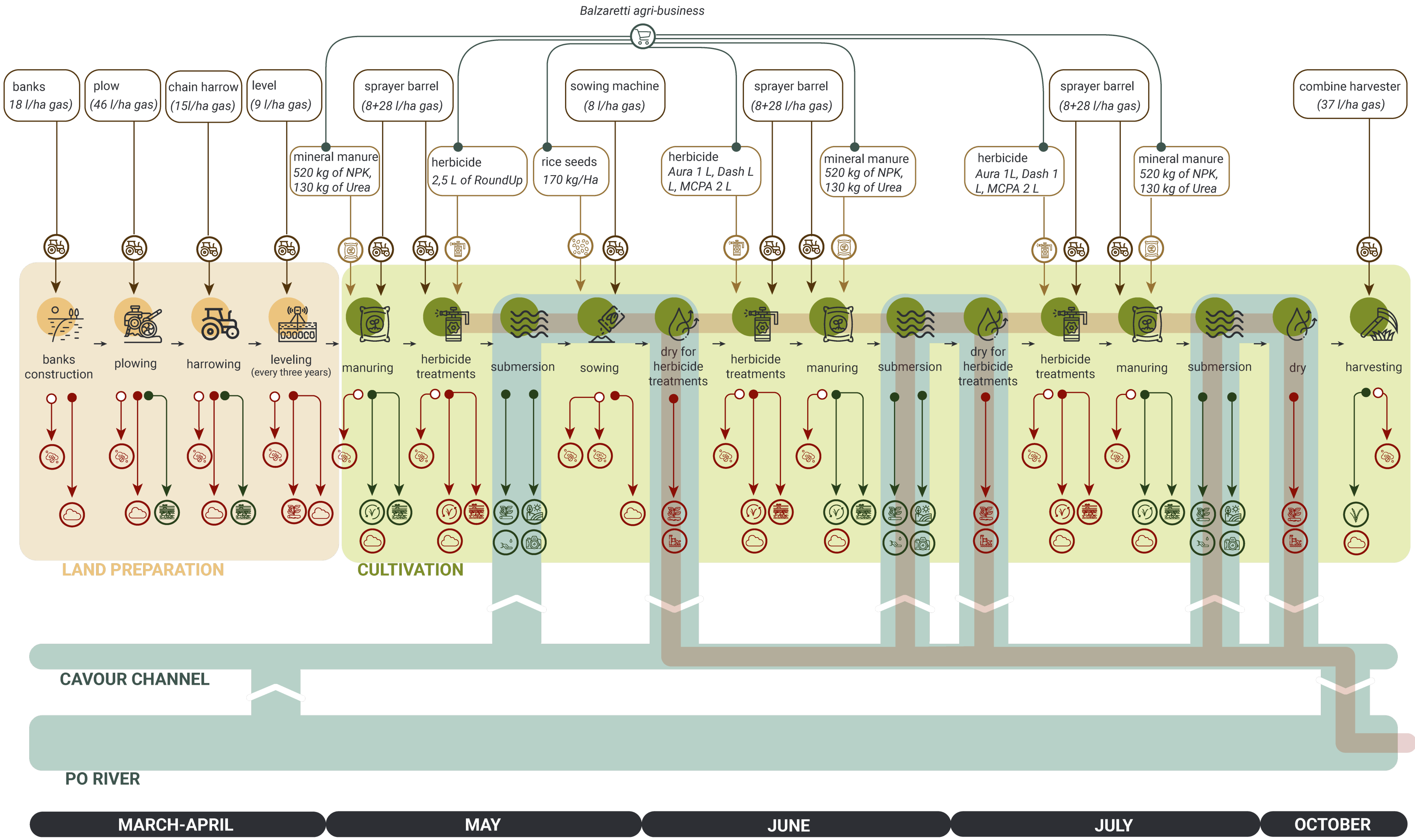


Fig.24 The graph represents a scheme of the cultivation technique: sowing in water with permanent submersion. In the upper part the inputs are represented, in order in the first place is the origin of the products used for cultivation, in the band below are listed the agricultural machinery used and the consumption of gas oil (l/ha) that they involve (Regione Piemonte, 2016). Below are the material inputs, which correspond to fertilizers, herbicides and seeds.
The timeline shows all the steps of cultivation and below it are listed the outputs as ecosystem services. In red are indicated the risks while in green are represented the beneficial services that the paddy field provides.
Water management has been represented in light blue and the time period in which the different actions occur in blue.

4.1.2
The biological technique: green mulching

The technique of green mulching comes primarily from Masanobu Fukuoka, a Japanese farmer and philosopher.
Convinced that nature is perfect and that problems arise when people try to improve it just so they can benefit from it, he studied for years a technique that would be as minimally invasive as possible.
His technique (natural farming) does not require agricultural machinery or chemicals, so it does not create pollution or consume fossil fuels. It also requires very little work for the farmer compared to any other method.
After thirty years of trying to achieve simplicity, he decided to stop plowing the soil to combat weeds.
His technique consisted in controlling them by covering the soil with white clover and a mulch of barley straw. After trying more than twenty types of cover he managed to find the one that could fight weeds and fix nitrogen.
Some tricks he implemented during his years of experiments, which sometimes resulted in the total loss of the crop, allowed him to obtain a cultivation in which he had to interfere as little as possible and a sustainable agricultural system.
Fukuoka proposes a way of life and a way of farming in which the process of healing the earth and purifying the human spirit takes place. Because these represent a single process, as natural agriculture derives from the spiritual health of man.
"Natural farming is not just for growing crops; it is for the cultivation and perfection of human beings" (Korn, 2003) (Fukuda, 2017) (Fukuoka, 1985).
Mulching is a technique that has numerous benefits. Winter cover used for the green mulching technique can recycle residual NO3 from the soil and convert it to N that can be used for subsequent crops. Also, legumes can be used as nitrogen fixers.
The mulch layer can also sequester atmospheric carbon and convert it to organic matter to improve soil quality, as well as having the aforementioned task of controlling weed growth, thus avoiding the use of herbicides (Dabney et al., 2001).

In Italy, the fontrunners of green mulching are the owners of the "Una Garlanda" company, the Stocchi family.
They began reducing the use of chemicals and practicing crop rotation starting in the 1990s, but it wasn't until the early 2000s that they turned to organic farming to produce natural rice.
They put back into the field ancient seeds obtained from the Ente Nazionale Risi and today they are the first organic seed company responsible for the conservation and production of ancient rice varieties.
Field experiments began in 2003 with Fulvio Stocchi on a land's portion of land. After years of attempts, tests of mixtures of different herbage, various times of flooding and drying he was able to reduce the invasive intervention on the fields and regain natural productivity. Today this technique is called Stocchi method or green mulching and allows to exclude the use of chemical products but also of natural fertilizers (Una Garlanda, n.d.).

In the green mulching technique (Figure 25) used by Priorato Farm, an herbage is sown immediately after the previous year's harvest and after harrowing. The species sown are giant red clover, villous vetch and ryegrass (25 and 15 kg/ha respectively) as they are nitrogen fixers.
In the spring, in May, rice is sown and the herbage is cut down soon after, thus creating a cover crop. The paddy field is then flooded and left in this state until the end of the rice season, i.e. before harvesting in October.
The part of the land cultivated with this practice needs much less human work, it is surely a less invasive technique than the one used in the remaining hectares of land.
This then brings benefits to the environment, but above all does not create obstacles to the development of biodiversity during the rice season. Indeed, many species have been recorded, in this section of the field, during the "Bioblitz".
Bioblitz is a naturalistic and scientific event, which consists in identify and classify animal and vegetal specie of a specific environment. The data collected are a useful tool for monitoring biodiversity (Regione Lombardia, 2020).

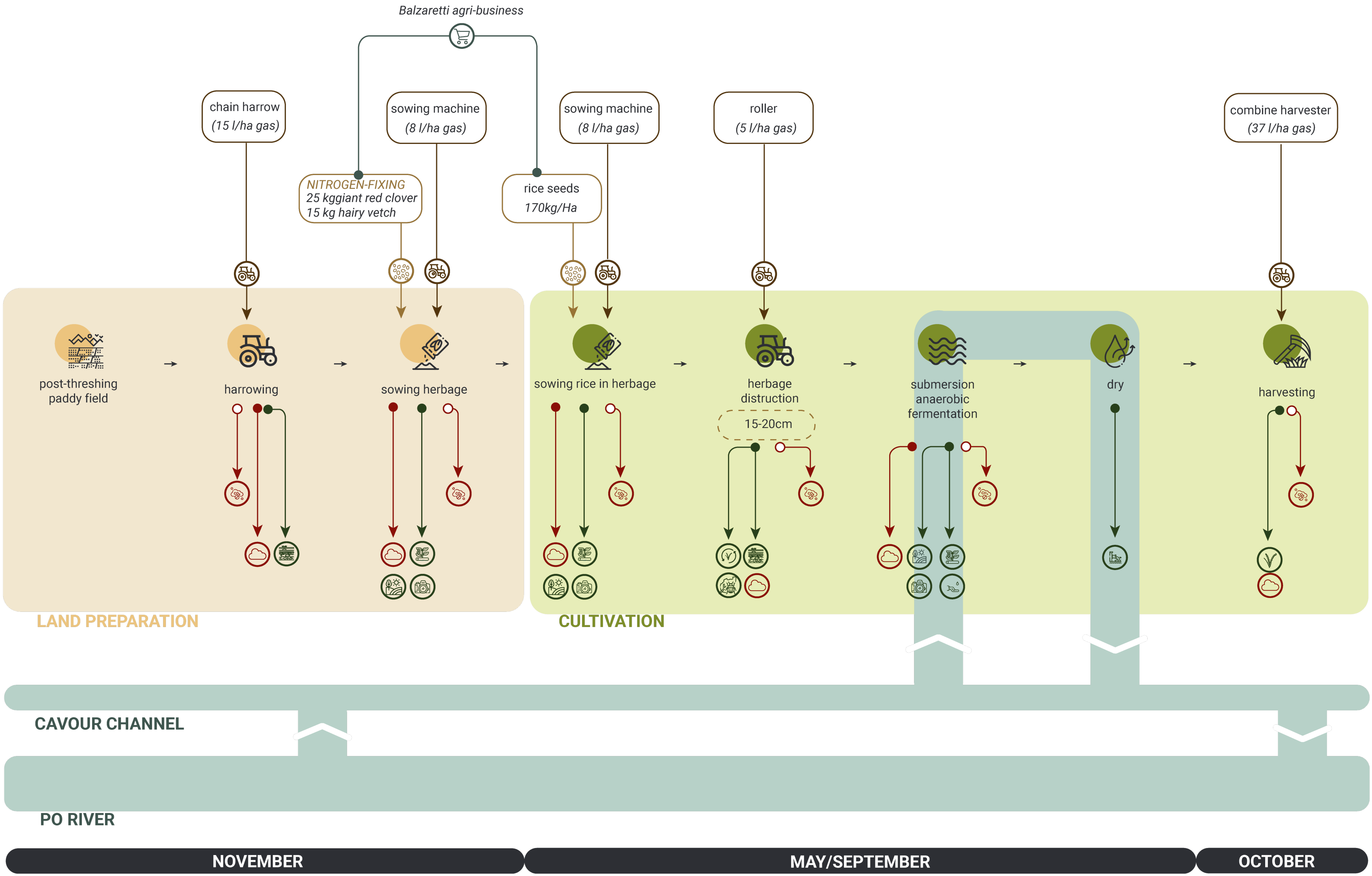


Fig.25 The graph represents a scheme of the cultivation technique: green mulching. In the upper part the inputs are represented, in order in the first place is the origin of the products used for cultivation, in the band below are listed the agricultural machinery used and the consumption of gas oil (l/ha) that they involve (Regione Piemonte, 2016). Below are the material inputs, which correspond to seeds both for rice and herbarium. The timeline shows all the steps of cultivation and below it they are listed the outputs as ecosystem services. In red are indicated the risks while in green are represented the beneficial services that the paddy field provides. Water management has been represented in light blue and the time period in which the different actions occur in blue.

4.2 Balance Sheet

The costs that the farm incurred in 2020 include: raw materials, combine harvester rental, electricity, water, maintenance and repair expenses, land rental, insurance and other general expenses. All of these cost items were respectively: 36.364,45 €, 3.659,49 €, 2.284,37 €, 10.480 €, 9.602,28 €, 30.000 €, 10.000 € e 3.958,94 €. The cost of raw materials was broken down into an additional four more specific items through assumptions. The four categories are: seeds, fertilizer, weeding and gas which sometimes have some differences between the two kinds of cultivation (Figure 26, 27 and 28).

Items	Quantity/ha	€/Quantity	€/ha
Seeds	170 kg/ha	340 €/t	57,8 €/ha
Fertilizer	355 kg/ha	35 €/q	122,5 €/ha
Weeding			155 €/ha
Gas oil		1338,30 €/1000 l	322 €/ha
Embankment construction	*18 l/ha*		
Plowing	*46 l/ha*		
Harrowing	*15 l/ha*		
Leveling	*9 l/ha*		
Seeding	*8 l/ha*		
Fertilizing	*8 l/ha*		
Weeding	*28 l/ha*		
Threshing	*37 l/ha*		

Fig.26 Conventional cultivation system expences (La coltivazione del riso, 2013) (Ismea Mercati, 2020) (Camera di commercio Biella e Vercelli, 2019) (Ente Risi, 2015) (Corteva Agriscience, 2016) (Ministero della Transizione Ecologica, 2020)(Regione Piemonte, 2016)

Items	Quantity/ha	€/Quantity	€/ha
Seeds	170 kg/ha	340 €/t	57,8 €/ha
Fertilizer	600 kg/ha	53 €/q	318 €/ha
Weeding			
Gas oil		1338,30 €/1000 l	108 €/ha
Embankment construction	*-*		
Plowing	*-*		
Harrowing	*15 l/ha*		
Leveling	*-*		
Seeding	*8 l/ha*		
Fertilizing	*8 l/ha*		
Weeding	*-*		
Threshing	*37 l/ha*		

Fig.27 Biological cultivation system expences (La coltivazione del riso, 2013) (Ismea Mercati, 2020) (Camera di commercio Biella e Vercelli, 2019) (Cornunghia, n.d) (Regione Piemonte, 2016)

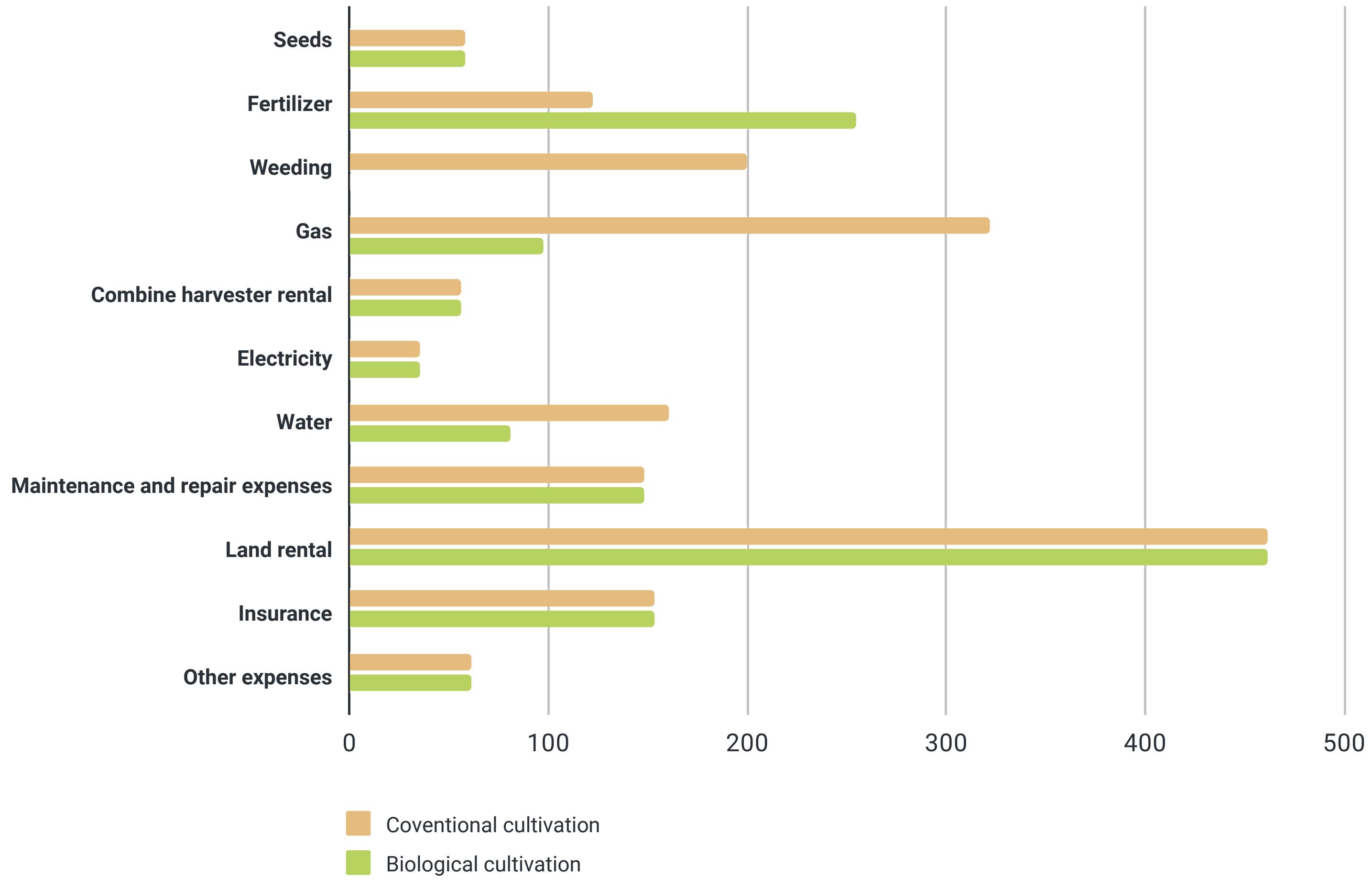


Fig.28 The graph shows the costs of 2020, in beige are represented conventional cultivation costs while in green the biological cultivation one.

Fig.29 The graph represents the balance sheet, on the left there are the indicators and, on the right, the corresponding numbers.

The sale of finished products amounted to 191.087,08 €. In addition, the company has received funding for a total of 39.000 €.
Shown below (Figure 29) is a simplification of the company's balance sheet in the year 2020 and the profit and loss graph (Figure 30).

BALANCE SHEET 2020	
ASSET	
Trade receivables	
cashing	191.087
revenue	191.087
Financing	
cashing	39.000
revenue	39.000
LIABILITIES	
Debt from suppliers for operating activities	
payment	56.026
cost	56.026
Debt from suppliers for general administrative expenses	
payment	13.959
cost	13.959
Debt from suppliers for raw material and finished goods	
Increase in raw material and finished goods	36.364
Decrease in raw material and finished goods	36.364
payment	36.364

PROFIT & LOSS 2020	
Gross profit	154.723
General administrative expenses	13.959
Total operating expenses	13.959
Suppliers	56.026
EBITDA	84.738
EBIT	84.738
Financing	39.000
Profit before taxes	123.738
Net result	123.738

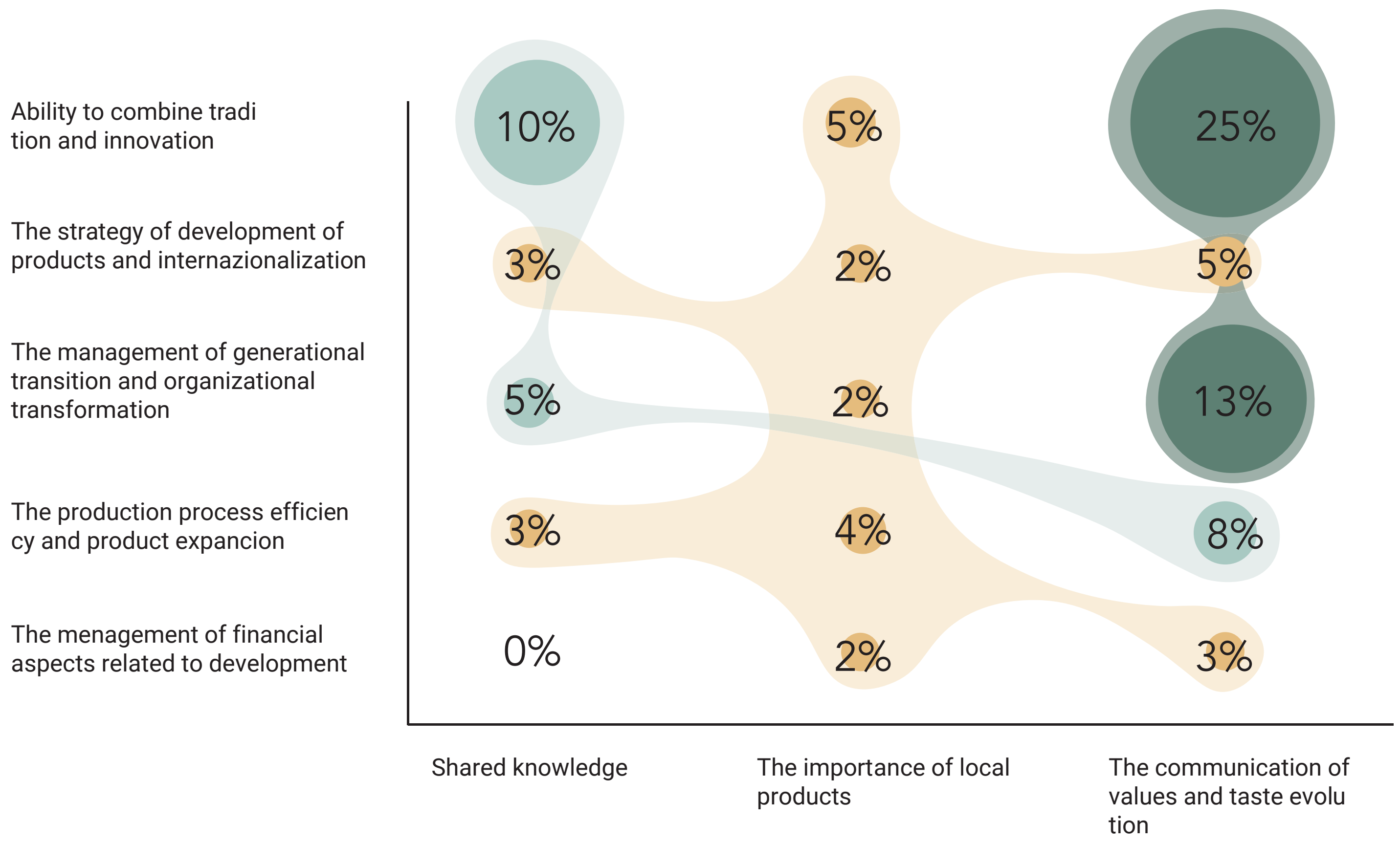
Fig.30 The graph represents the profit and loss scheme, on the left there are the indicators and, on the right, the corresponding numbers.

4.3 Linear matrix

As shown in Figure 31 the company's greatest strength is its inclination towards innovation, but always keeping traditions as a reference, from which lessons can always be learned.
In fact, the head of the company argues that in order to fight the industrialisation of agriculture, it is necessary to rediscover the techniques of the past and improve them thanks to new technologies, both to improve the quality of the product, but also to respect the environment in which it operates and the species that live there.
The desire to involve as many producers as possible in these ideals has led him and some of his colleagues to set up an association that promotes certain values such as respect for ecosystems and biodiversity.
So, overall, Priorato company has a good ability to combine tradition and innovation, and an inclination towards transformation, partly due to the influence

Fig.31 Analysis of the company current situation. In the x- and y-axes the evaluation parameters are positioned. With a percentage >12 the focus area is highlighted, with percentages ranging from 5 to 12 the attention area is represented and finally with percentages <5 the hinted presence area is pointed out

of Polyculturae association to which are due the knowledge of green mulching technique.
The company is already in a good position, however, some improvements can be done about some subjects. For example, expand knowledge through the study of research carried out in other countries, make the best use of local resources and prepare a solid financial plan for development.



4.4 S.W.O.T.

After an accurate overview of the company features and on the economic situation, a SWOT Analysis (Figure 32) has been carried out.
As seen before this is an evaluation tool useful to clarify which are the strength, weaknesses, opportunities and threats of an organization, and the result is the creation of some strategies to carry out to improve the business. So, all the information collected in the previous chapters have been used and analysed to build the SWOT.

#Strengths

Overall, the farm's strengths are related to the attention given to biodiversity and the experimentation of sustainable agricultural techniques. Indeed, the company has obtained the certification Biodiversitas for its commitment to sustainable agriculture thanks to the biological cultivation and the construction of a ditch near a chamber where water is stored during the entire production cycle to allow some species to complete their life cycle. In addition, where biological rice is grown the presence of many animal species has been recorded such as birds, *odonatan, amphibians, reptiles*.

#Opportunities

First of all, there is the opportunity to expand the cultivation of biological rice to all the hectares and to adopt the natural farming practices (Fukuoka, 1985). Moreover, it is possible to combine several agroecological techniques such as farming and breeding in rice paddies (Chinase Academy of Science, 2010).
As rice field represent a complex ecosystem rich in fauna and knowledge due to the particular technique that are used to produce rice, rice ecosystem can be exploited for educational purposes, ecotourism and recreational activities.

#Weaknesses

The farm weaknesses are mainly related to the field

STRENGHTS

1. The company shows attention in the respect of biodiversity and in the experimentation of sustainable agricultural techniques
2. The company has obtained the certification Biodiversitas
3. 26.7 hectares are biologically cultivated
4. A ditch has been dug near a field where water is stored during the entire production cycle to allow some species to complete the life cycle
5. In the field where biological rice is grown there is the presence of a rich fauna

WEAKNESSES

1. The cultivation of rice produces methane and nitrous oxide emissions.
2. In the conventionally cultivated field pesticides and chemical fertilizers are used
3. In the conventionally cultivated field processing is intense
4. In the conventionally cultivated field, repeated submersion and dryness are carried out
5. Biological cultivation proportionally produces 15% less rice

OPPORTUNITIES

1. Expanding the cultivation of organic rice to all the hectares in possession would bring the improvement of the farm in some areas
2. "Agriculture of the mu" (of not doing), i.e. minimizing as much as possible the interventions of man, which is limited to support a process largely managed by nature, rejecting the traditional and modern agricultural techniques
3. In rice paddies it is possible to combine several agroecological techniques such as duck-rice farming and fish-rice farming
4. Rice ecosystem can be used for educational purposes with school projects
5. In the rice paddies it is possible to carry out different activities such as birdwatching
6. In the rice paddies it is possible to promote ecotourism thanks to the characteristic landscape and the different activities in contact with nature that can be carried out.

THREATS

1. Water may be contaminated by chemical residues from nearby crops
2. Rice cultivation is vulnerable to diseases that can affect the quantity and quality of the crop
3. The ecosystem can be endangered by non-native species such as the Louisiana red shrimp
4. Drought could cause damage to rice production
5. Abnormal weather conditions could cause damage to productivity

Fig.32 The graph represents a diagram of the SWOT analysis of the rice ecosystem, from the left can be found the strengths, opportunities, weaknesses and threats.

portion cultivated traditionally, indeed here are carried out repeated submersion and dryness, and also the process is intense, many treatments including chemical herbicide, pesticide and fertilizer are used to obtain rice and to improve soil quality and to manage weeds and pests.
Among biological cultivation weaknesses it is possible to notice that proportionally it produces 15% less rice. Furthermore, rice cultivation produces CH_4 and N_2O emission (Peyron, et al., 2016).

#Threats

The company must consider also some external threats. In fact, the incoming water could be contaminated by chemicals used in nearby crops where biological cultivation techniques are not applied. Moreover, there are some factors difficult to control that could cause damage to production, for instance diseases of the rice plant or infestations of exotic animals such as the Louisiana red shrimp. Threats can also come from unfavourable weather conditions during the rice season or drought.

4.5 Strategies

After the SWOT Analysis some strategies have been built combining the different categories.
In this case two kind of strategies have been proposed: SO strategies and WO strategies.

Priorato farm cultivates almost half of its properties with the biological technique of green mulching, moreover it shows great interest in all those practices that respect the environment and biodiversity. For example, recently a ditch has been dug on the side of a field in order to allow some species to survive and to conclude their life cycle during dry periods.
These strengths that characterize the farm, have been taken into consideration in order to exploit the opportunity to extend the biological cultivation to the remaining hectares of the farm.
The implementation of this operation would bring several improvements. First of all, the operations to be done in the field would be fewer, therefore decreasing

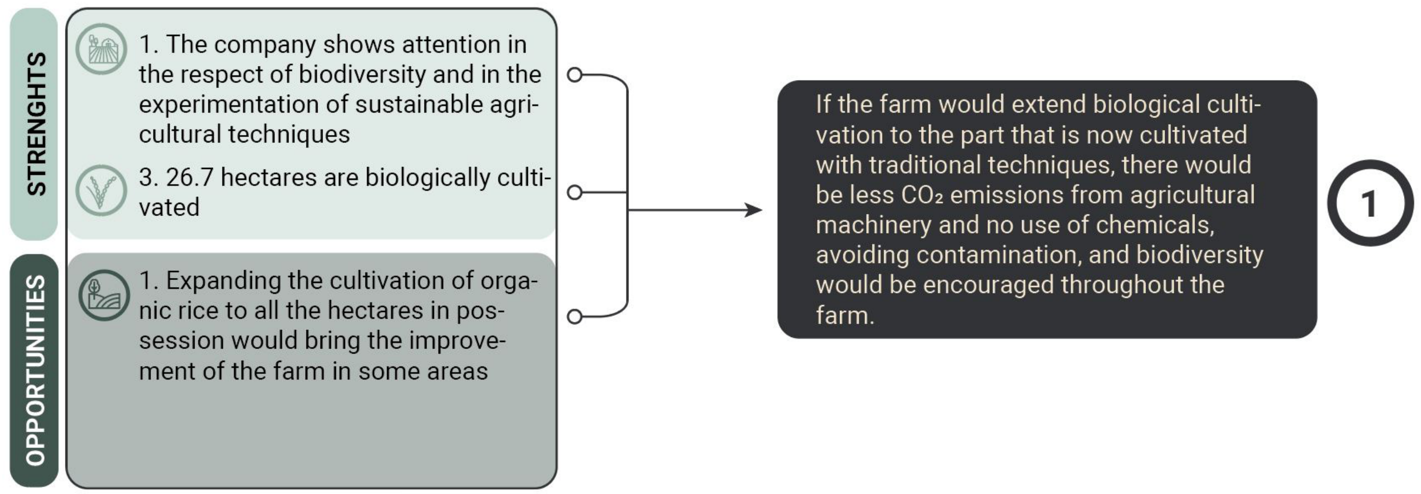


Fig.33 In the chart, there are a few categories from the SWOT that have been combined to create the first strategy.

the use of agricultural machineries. Moreover, with the use of green mulch it is possible to avoid the use of pesticides and fertilizers altogether, using an organic one if necessary. This then leads to a better quality of rice, soil and water avoiding contamination (Figure 33).

Taking into account the strengths also mentioned before, another opportunity could be exploited. Also, the same opportunity can be exploited to improve some weaknesses.
This strategy (Figure 34) is very similar to the previous, the aim is to reduce man intervention in the rice paddy. However, the proposed technique is one of “not doing”. As explained before, this technique comes from Fukuoka, a Japanese botanist and philosopher, pioneer of natural farming.
He was convinced that nature is perfect and that problems arise when people try to modify it with the only goal of benefitting from those changes; with this in mind Fukuoka studied for years a technique that would be as non-invasive as possible.
Indeed, he managed to create a new system that does not require agricultural machinery or chemicals and thus works without generating pollution excluding, in fact, the consumption of fossil fuels. Fukuoka’s technique deals with the control of weeds by covering the ground with white clover and a mulch of barley straw.
During his experiment, the Japanese botanist was able to create a cultivation system in which human intervention was needed as little as possible (Fukuda, 2017) (Fukuoka, 1985) (Korn, 2003).

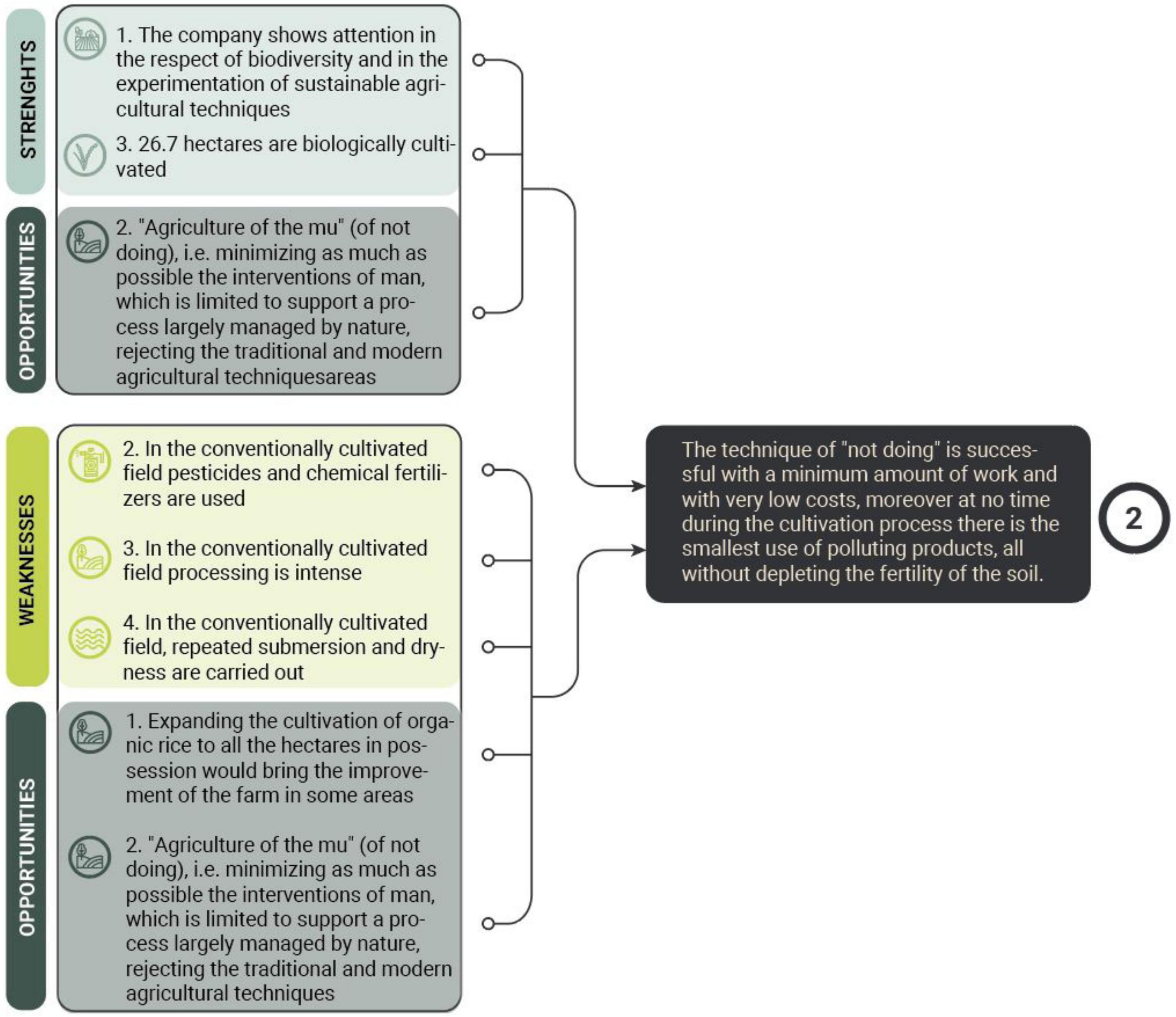


Fig.34 In the chart, there are a few categories from the SWOT that have been combined to create the second strategy.

Thanks to the “bioblitz”, it has been possible for the company to record the presence of a rich fauna in fields where rice is grown biologically. As a matter of fact, many species were found such as birds, *odonatan, amphibians, reptiles*.
So, this strength could be taken into account to exploit the opportunity to carry out educational and recreational activities.
Activities such as birdwatching or hiking or horseback riding along the banks of the rice paddies can be organized to increase the farm’s income. Moreover, some farms organize didactic activities for children in which they are instructed about the cultivation of rice through laboratories in which they can do some work in

the agricultural field.
These educational activities in contact with nature, besides bringing a higher profit to the company, are very important to educate all generations to respect the ecosystem and to generate awareness (Figure 35).

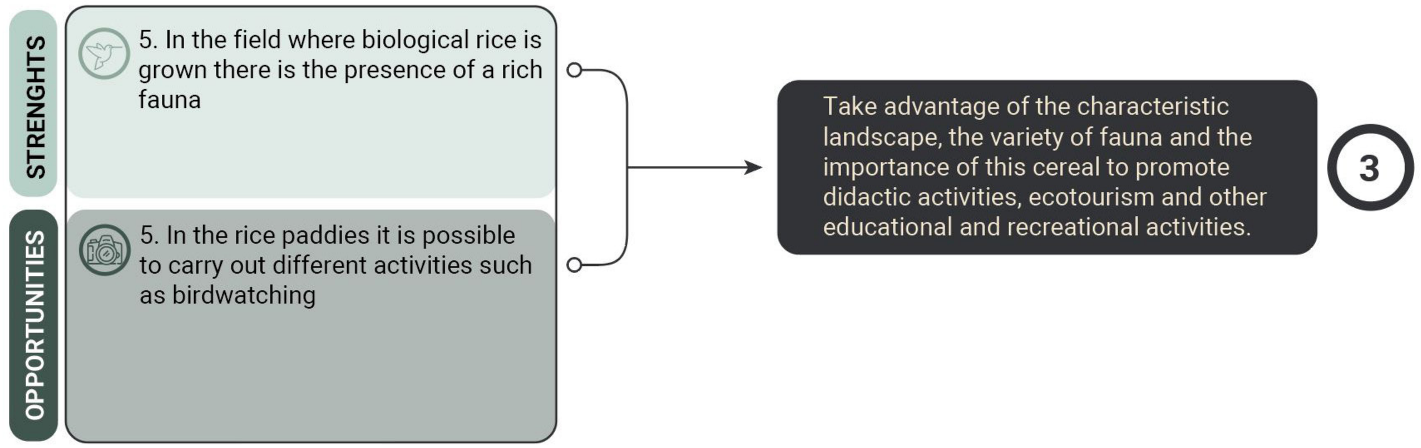


Fig.35 In the chart, there are a few categories from the SWOT that have been combined to create the third strategy.

In this strategy (Figure 36) the aim is to exploit the ditch dug by the company, to save some species from the ecological trap.
Indeed, rice fields, as has been written before, are a temporary wetland, this means that water could be absent for long or short periods. Many species who complete their life cycle in water are endangered by the repeated dryness and some new techniques such as the laser leveller, which destroys water ponds, thus causing the loss of biodiversity. Indeed, thanks to the inaccuracy of the old techniques, many species were able to complete their life cycle, while, now, with the implementation of these advanced technologies, that aim at maximizing the productivity of the field, there are no more water ponds during the dry periods, threatening the survival of biodiversity.

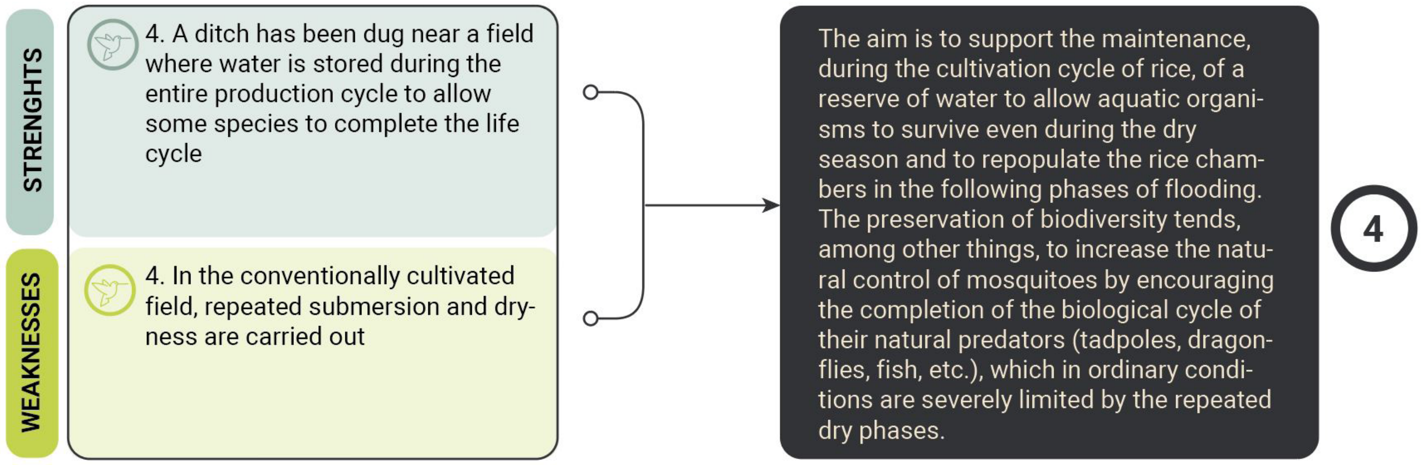


Fig.36 In the chart, there are a few categories from the SWOT that have been combined to create the fourth strategy.

Taking into account the interest of the company in respecting the rice ecosystem, this can be used to exploit the opportunity to combine different agroecological techniques, thus improving a weakness given by the production of emissions from rice cultivation.
Indeed, the introduction of ducks and fish, for example, in the rice field could bring many benefits.
These animals are able to naturally control pest and weed growth, thus eliminating the use of chemicals, which guarantee a healthier environment by avoiding water and soil contamination but also less expenses for the company.
Furthermore, fish and ducks improve the quality of the soil by enriching it with nutrients avoiding the use of fertilizer in traditional cultivation and organic fertilizer in biological one (which is even much more expensive than the chemical one). Moreover, they increase the profit of the company, adding food products that can be sold, such as fish and duck meat and duck eggs. They also regulate the emissions produced by the agricultural system.
So, to resume this strategy (Figure 37) help to create an healthier environment but also is economically convenient for the business.

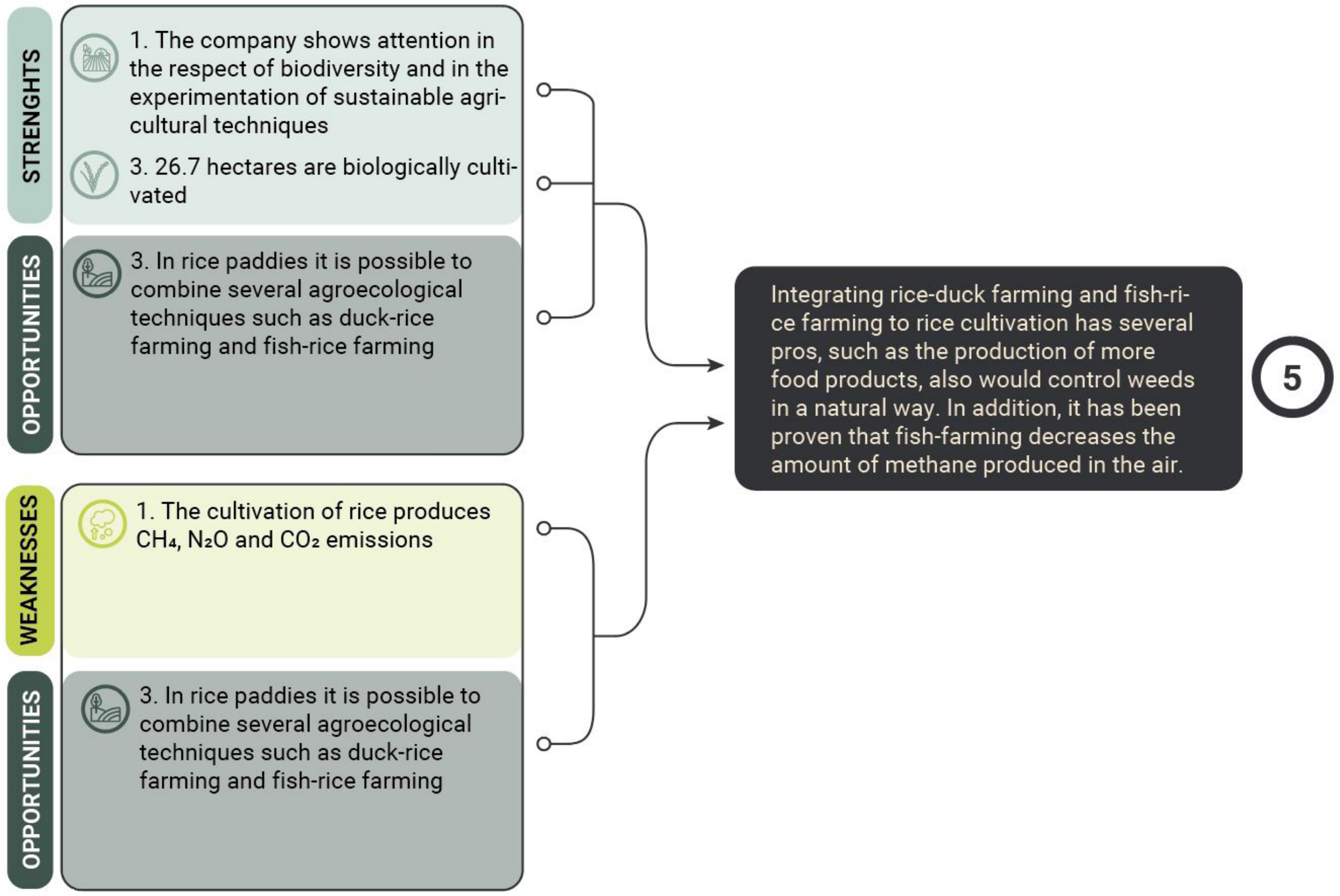


Fig.37 In the chart, there are a few categories from the SWOT that have been combined to create the fifth strategy.

This strategy (Figure 37) has been chosen for the implementation of the rice agroecosystem, because it brings, as it is written before, benefits from different point of view.
In the next chapter, the argument concerning this strategy will be explored through field research in which the two systems were tested both individually and together, collecting quantitative data useful for this research.

Photo by Avinash Kumar on Unsplash

5.0 Integrated farming

Integrated farming is the integration of different activities such as cropping system, breeding, horticulture, fishery, apiary, and agro-forestry to optimize the use of company resources. It brings numerous ecological advantages and also it should be able to give an additional income to the farm and also generate employment.

This system was practiced first in those countries that were already facing a resource crisis, now it is spreading all over the world. Indeed, the pressure provoked by the increasing population on the earth and the rise in the demand for food, water, etc. has led to the overexploitation of natural resources. From this problem has grown the necessity to integrate different local natural resources on a single plot (Behera, Panighrahi, & Sarangi, 2012).

This method has been assessed to produce food in an effective way, to restore the natural ecosystem and to generate diversity and as a consequence the system resilience. Indeed, uniformity is always associated with vulnerability, on the contrary, an agroecosystem characterized by diversity develops a strong capacity for adaptation and resilience (Altieri, 2018) (Koohafkan, Altieri, & Holt Gimenez, 2012).

5.1 Rice-duck farming

Takao Furuno, a Japanese farmer, after being inspired by Rachel Carson's book named Silent Spring, decided to move toward biological farming. The first ten years were extremely complicated, the biggest problem was avoiding the use of chemicals.
After some hesitation, in 1988 he started to experiment the introduction of ducks in rice paddy in his own field. The technique involved the release of 15/20 ducks per 1.000 square meters in June when the seedlings have been planted from about one or two weeks, and before the harvest, in September, were recaptured. He got excellent results, indeed ducks feed on insects and weeds, thus solving the problem of avoiding the use of chemicals. Moreover, the movement of ducks' paws helps to oxygenate the water thus improving

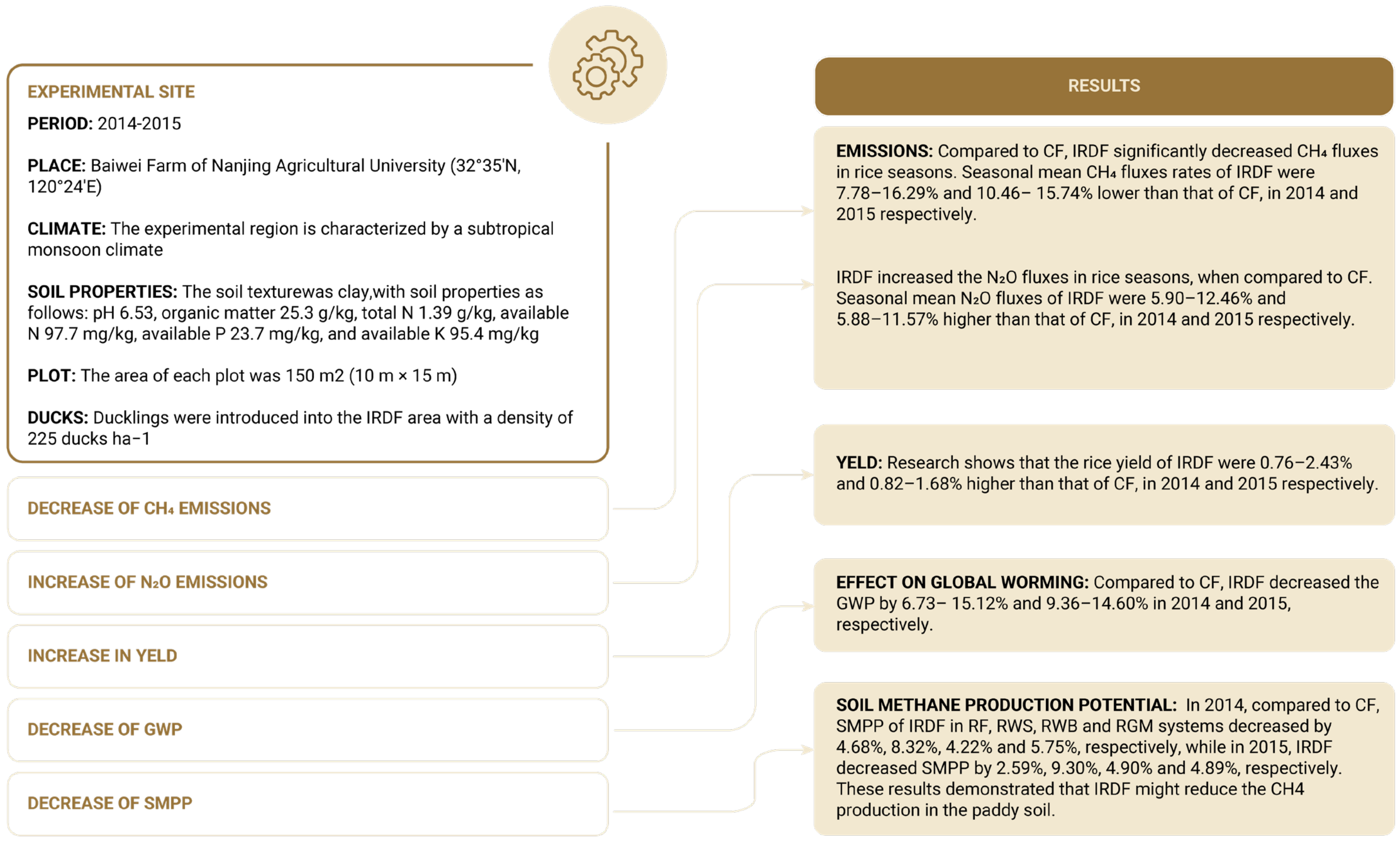
Living Circular. (2015, Gennaio 7). Takao Furuno and his "duck rice". Tratto da Living Circular: https://www.livingcircular.veolia.com/en/inspirations/takao-furuno-and-his-duck-rice

productivity. Furthermore, their droppings serve as a natural fertilizer.
The first years of the experiment were difficult, but as time goes by Furuno learned how to manage the field and he improved his integrated system. For instance, he built an electrified enclosure to prevent the ducks from being decimated by packs of stray dogs, and also he learned that a shelter is needed where ducks can rest and protect themselves from rain.
A lot of years of research have led also to deep knowledge and he understood which was the more suitable species of ducks to use, as a matter of fact, Aigamo ducks (*Anas platyrhynchos domesticus*) turn out to be the best species, as they do not migrate and are common to find, as well as having excellent meat.
Furuno method provides a further economic benefit and also an additional food product: biological ducks meat, thus increasing food security at a local and regional level. Furthermore, it requires little human work and expenses (Living Circular, 2015) (Assaë, n.d.).

5.1.1 Quantitative data

To prove that actually the integrated farming of ducks and rice brings many benefits, research has been done that takes into account several case studies from around the world.
Below, will be listed the most significant papers, arranged in synthetic schemes where it is possible to find the main features of the study, such as location, climate, soil characteristics, the area reserved for the experiment, and indications of the species introduced in the field.
In addition, the benefits that each study demonstrates are specified with quantitative data.

The experiment represented in Figure 38 was conducted in 2014 and 2015.
The data collected in 2014 show that after the introduction of ducks into the paddy field, CH_4 emissions decreased by the 7.78/16.29%, N_2O emissions, on the other hand, increased by the 5.88/11.57%, in addition, it can be said that productivity increased by the 0.76/2.43%. Moreover, the GWP



***GWP:** Global Worming Potential; **SMPP:** Soil methane production potential; **CF:** conventional farming; **IRDF:** Integrated rice-duck farming; **RF:** rice-fallow; **RWS:** annual straw incorporating in rice–wheat rotation system; **RWB:** annual straw-based biogas residues incorporating in rice–wheat rotation system; **RGM:** rice green manure

Fig.38 In the scheme, a summary is represented of a case study concerning the rice-duck farming system (Xu, Liu, Wang, Yu, & Hang, 2017)

decreased by the 6.73/15.12% and the SMPP by the 5.75% in the plot treated with green manure.
On the other hand, the data collected in 2015 show that after the introduction of ducks in the paddy field, CH4 emissions decreased by the 10.46/15.74%, N2O emissions instead went up by the 5.88/11.57%, moreover, it can be said that the productivity increased by the 0.82/1.68%. Furthermore, the GWP decreased by the 9.36/14.60% and the SMPP by the 4.89% in the plot treated with green manure (Xu, Liu, Wang, Yu, & Hang, 2017).

The study illustrated in Figure 39 shows that thanks to the introduction of ducks in rice fields it is possible to control the presence of insect pests, moreover the presence of weeds is about 90% under control thanks to duck's activity.
Productivity has increased by 20% while profit has increased by 50-60%.

Moreover, it has been demonstrated that duck droppings enrich the soil with nutrients, and their movement aerates the soil, avoiding the accumulation of harmful gases, thus enhancing soil quality (Hossain, Sugimoto, Ahmed, & Islam, 2005).

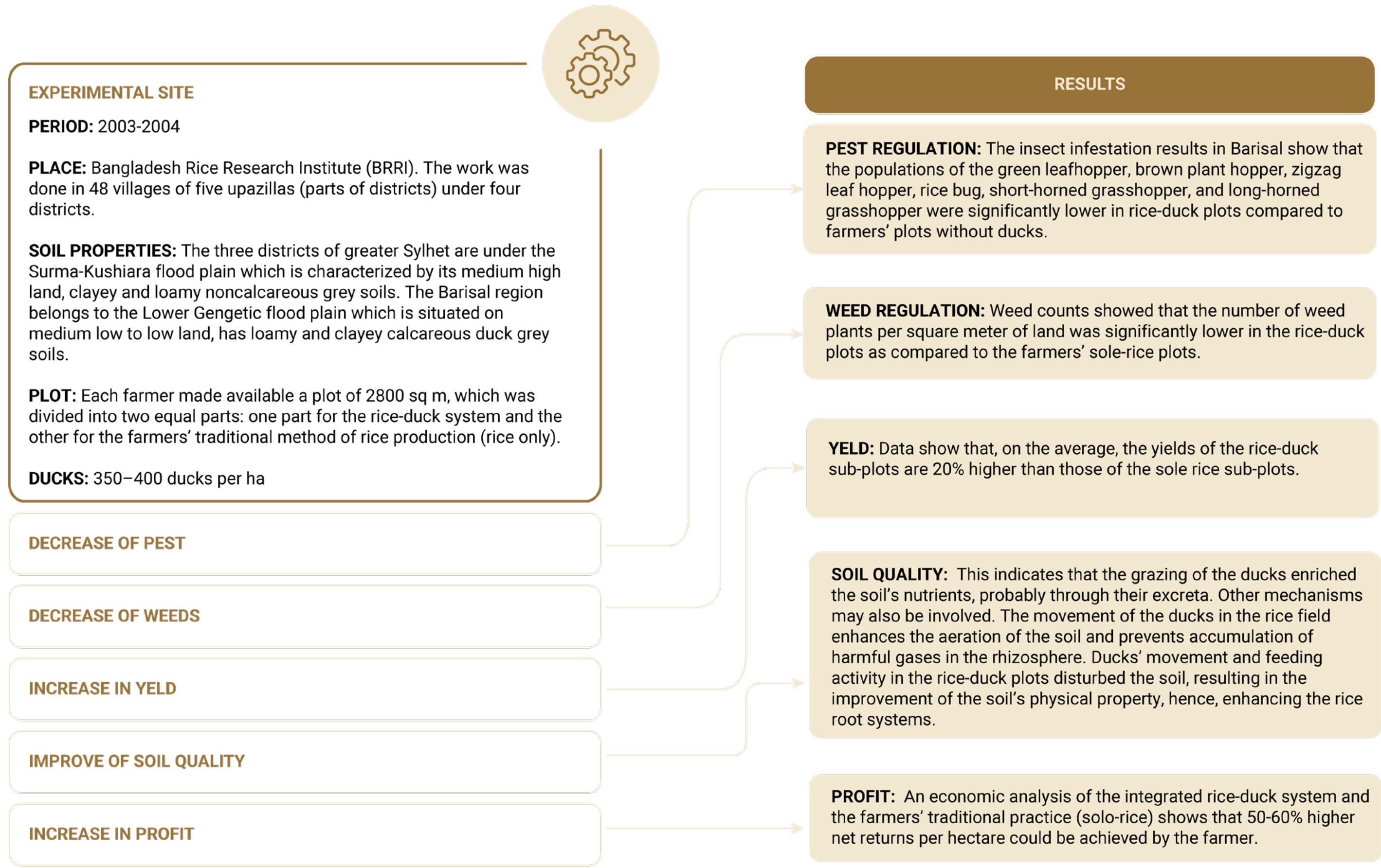
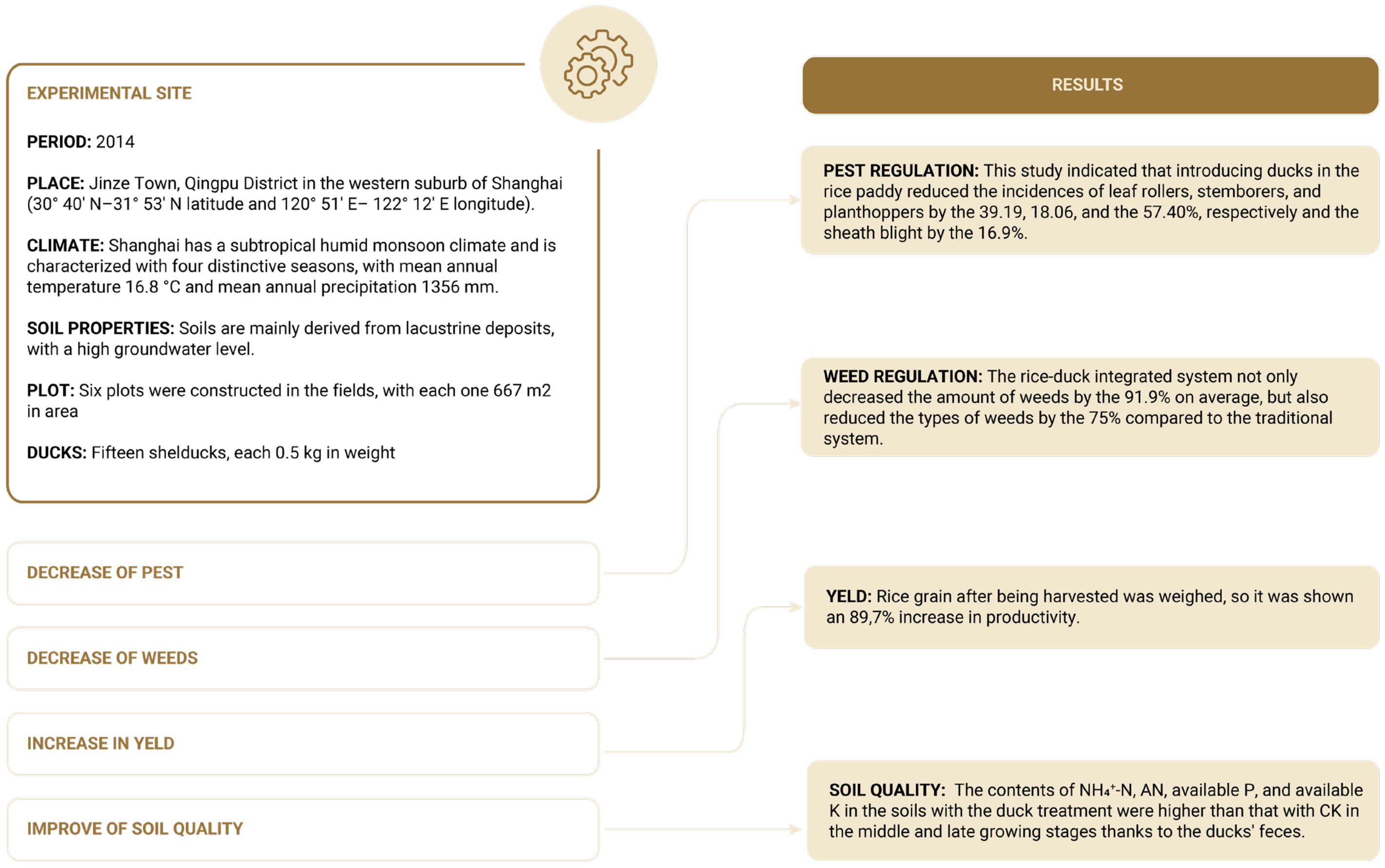


Fig.39 In the scheme, a summary is represented of a case study concerning rice-duck farming system (Hossain, Sugimoto, Ahmed, & Islam, 2005)

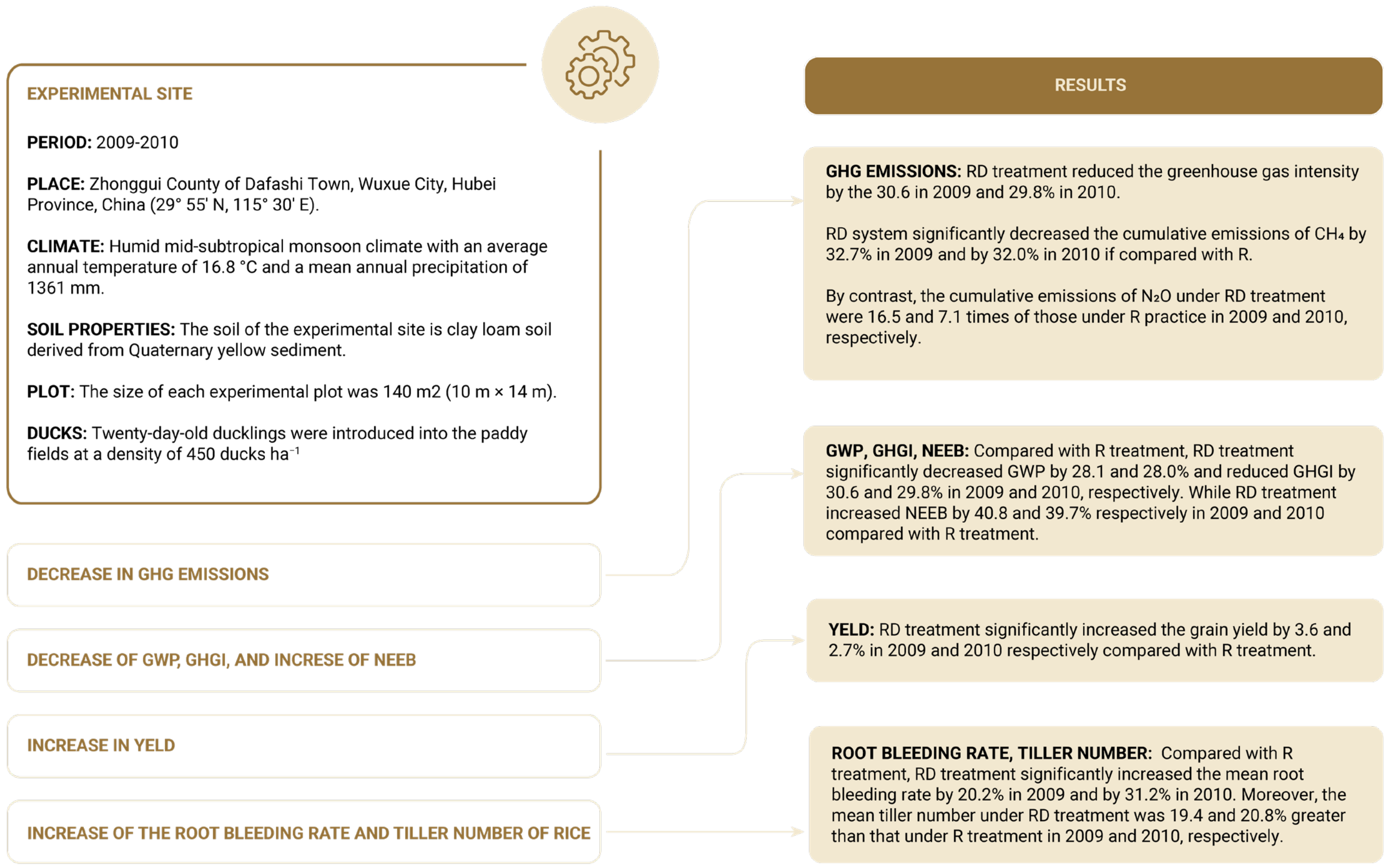
The Figure 40 shows the data collected from a Chinese study which demonstrate that ducks are able to control weeds and pests, indeed the presence of leaf rollers, stemborers, planthoppers and sheath blight has decreased by the 39,19%, 18,06%, 57,40 %, and 16,9% respectively. Moreover, a decrease in types of weeds has been detected, about the 75%, and the total amount of weeds was reduced by the 91,9%.
In addition, ducks' faeces increased nutrients stored in the soil (Teng, et al., 2016).



***NH_4^+-N:** Ammonium-Nitrogen; **AN:** alkali-hydrolyzable N; **P:** phosphorus; **K:** potassium; **CK:** non-duck treatment

Fig.40 In the scheme, a summary is represented of a case study concerning rice-duck farming system (Teng, et al., 2016).

Figure 41 shows schematically the data collected from a study conducted in China.
The research showed that by introducing ducks in the paddy field chamber it is possible to decrease by the 29-30% the greenhouse gas emissions, in fact the total emissions of CH_4 were found to be about the 32% lower thanks to this system. On the contrary, N_2O emissions are higher than in a traditional rice cultivation system. Another important finding is the decrease in global worming potential of about the 28%.
Concerning the effects on the rice plant, it was found that the mean root bleeding rate increased by about the 20-30% in the two years of the experiment, thanks to the introduction of ducks. In addition, the mean tiller number increased by the 19-20% for the same reason. The introduction of ducks in the paddy field also increased productivity by about the 2-3% (Sheng, Cao, & Li, 2018).



***GHG:** Greenhouse gas; **RD:** Rice-duck farming; **R:** Rice farming; **CH_4:** Methane; **N_2O:** nitrous oxide; **GWP:** Global warming potential; **GHGI:** GWP=grain yield; **NEEB:** net ecosystem economic budget

Fig.41 In the scheme, a summary is represented of a case study concerning rice-duck farming system (Sheng, Cao, & Li, 2018).

Figure 42 shows data collected by Shiming and Gliessman in the book Agroecology in China: Science, Practice, and Sustainable Management.
The introduction of ducks has been shown to bring numerous benefits. One of these is the ability to eliminate the use of pesticides as the system is able to regulate pest growth. In fact, the number of damaged leaves decreased significantly, weed biomass decreased by the 98%, and rice diseases also decreased dramatically.
Due to the conditions created by the introduction of ducks in rice fields, there was an increase in the arthropod community's biodiversity ranging from about the 11% to the 17%.
Finally, an improvement in soil quality was demonstrated due to an increase in certain elements such as organic matter, nitrogen, phosphorus, and potassium (Shiming & Gliessman, 2016).

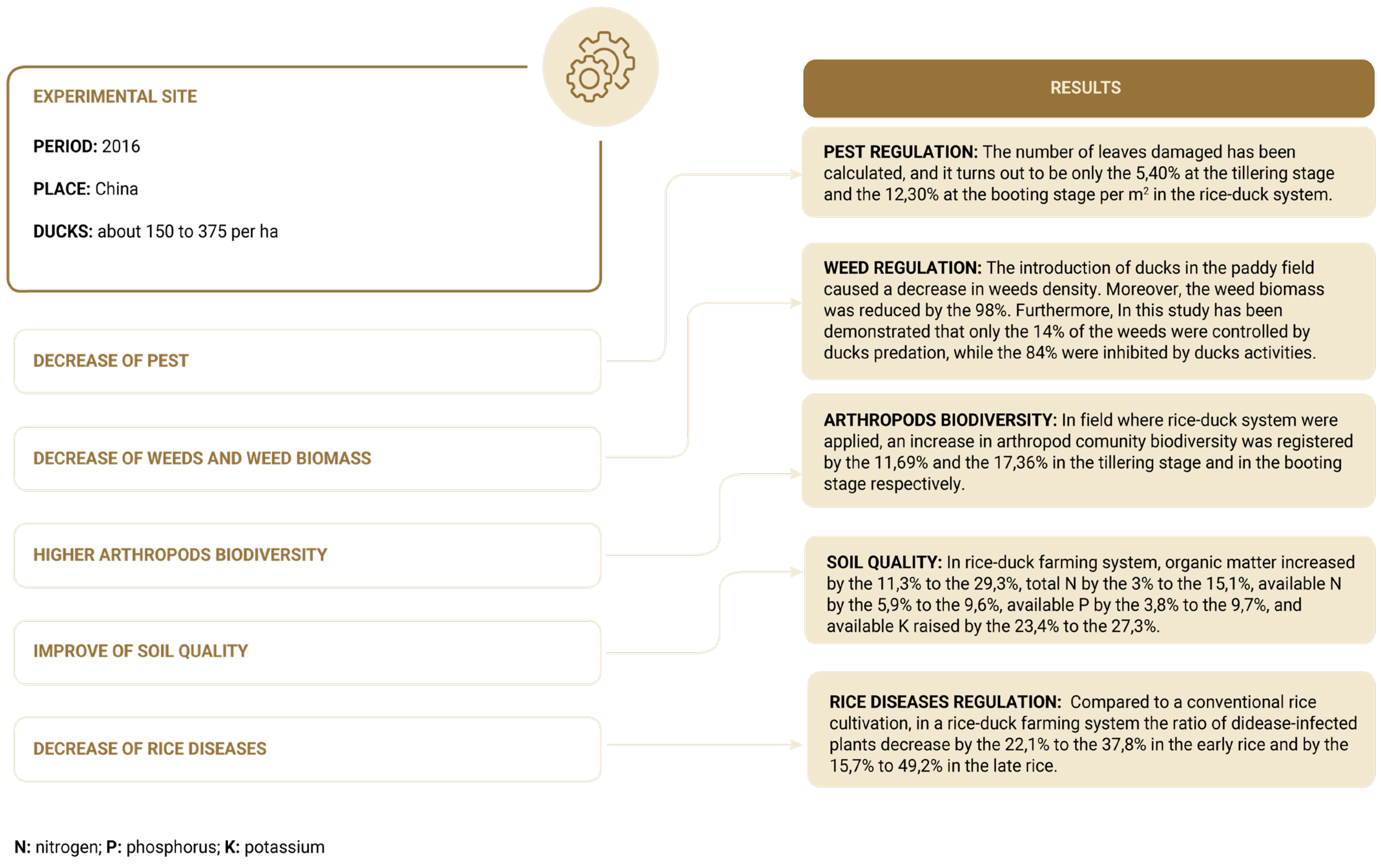


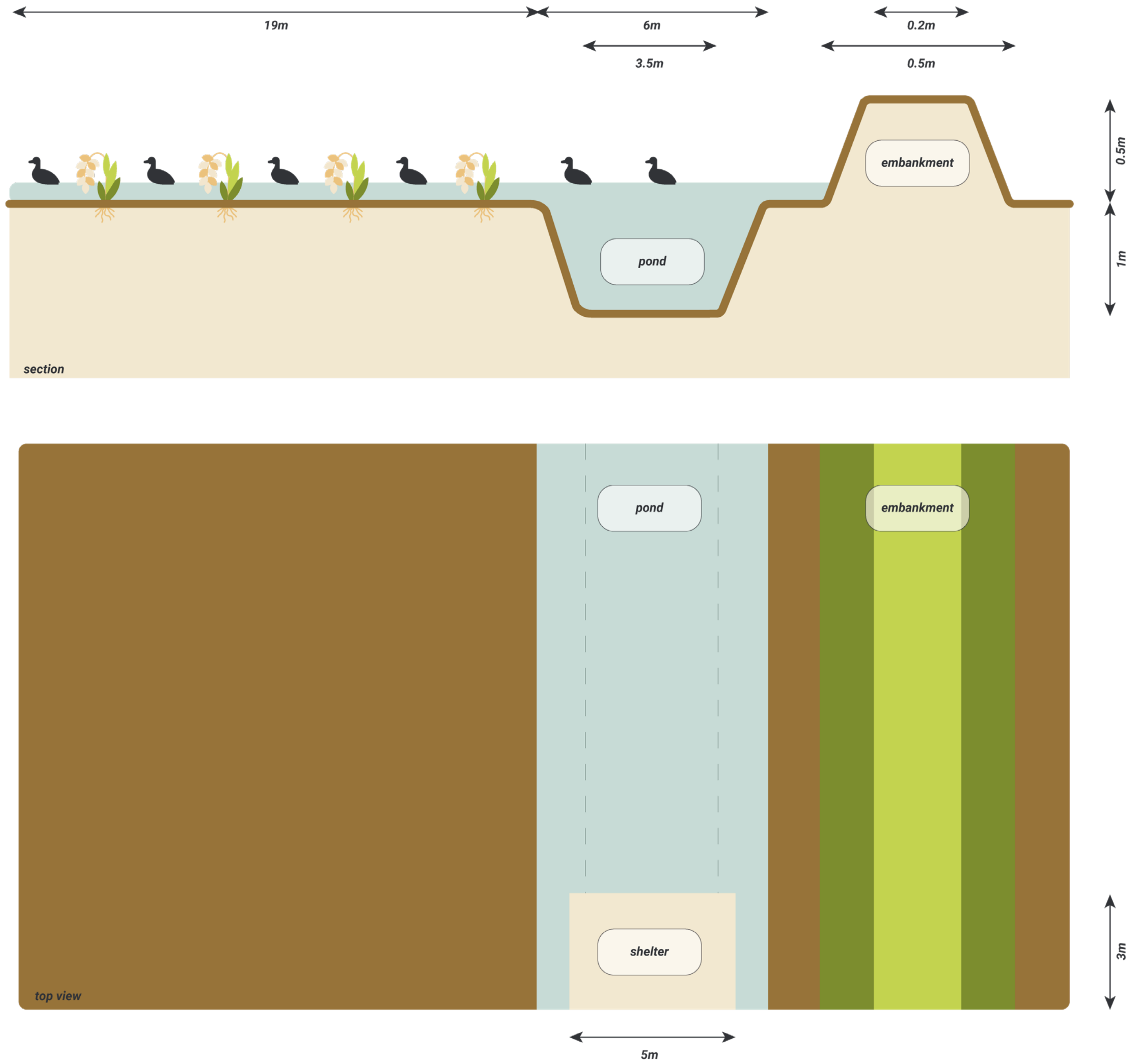
Fig.42 In the scheme, a summary is represented of a case study concerning rice-duck farming system (Shiming & Gliessman, 2016).

5.1.2
Field preparation for the introduction of ducks in rice cultivation

To host ducks in the paddy field chamber, some adjustments are needed (Figure 43).
Here an Indian case study has been taken into account to establish which are the changes to be done.
The field taken as example is at the National Rice Research Institute, Cuttack, Odisha, India (20° 25 N, 85° 55 E; elevation 24 m above mean sea levels).
The plot used for the experiment was 375 m² (25 m long and 15 m wide) and on one side a pound, having 1 m depth and 6 m wide, has been dug to provide water to ducks in case the field is dried, the pond is also useful at the end of the rice season for ducks' harvest.

Furthermore, a duck shelter needs to be constructed to protect ducks during the night, in this case, a 3 m x 2 m shed was placed above the pond.
Another measure that was implemented, was to place a one meter high fish net around the field to prevent the ducks from going to other fields (Nayak, et al., 2018).

Fig.43 Rice-duck farming field construction (Nayaka, et al., 2018).



5.2 Rice-fish farming

The rice-fish system is an important source of income and animal protein for farmer because it allows aquaculture, this is the reason why this system was widely used in the past (even in Italy) and still today in developing countries, in fact integrated production gives the possibility to obtain more food products from a limited space.
In rice-fish system, fish are grown simultaneously or by turns with rice in the paddy field or in a rice/pond system. They may be purposely introduced or they may enter the paddy field chamber naturally through waterways.

Haq, N. (2014, January 27). R&D can boost rice-fish farming in Bangladesh. Asia & Pacific. https://www.scidev.net/asia-pacific/news/r-d-can-boost-rice-fish-farming-in-bangladesh/

This production is mainly spread in Asia where local species are bred such as: white fish (for instance *Rasbora, Puntius, Trichogaster*), and black fish (for example *Channa, Clarias, Anabas, Ompok*). Sometimes also exotic and wild aquatic species are introduced such as *Cyprinus, Oreochromis* and *Hypophthalmichthys*.
Fish are usually introduced at rate of 0,5-1 fish/m2 into the paddy field when it is flooded, then may be caught or possibly collected before harvest when the paddy field is dried. For example, in a Cambodian case study, 2.500 common carp, 1.200 silver barb, and 1.250 tilapia were included per hectare.
Generally this system could produce a range of 1,5 to 174 kg/ha of fish meat every rice season, but obviously numbers depends on the kind of species and the management used (Rice Knowledge Bank, s.d.).
This kind of system has many benefits besides fish yield, in the next paragraph they will be listed through the analysis of real case studies.

5.2.1 Quantitative data

As for rice-duck farming system, quantitative data have been collected to prove rice-fish system benefits. Some real case studies are listed below, all of them are Asian. In order to immediately understand the most significant features, all the papers have been schematized to simplify the reading.
First of all the study characteristics are reported, then, below, the main benefits are pointed out with a brief description.

A study conduced in China (Figure 44) between 2016 and 2018 demonstrate that a co-culture of fish and rice could decrease pest and weeds, indeed data shows a decrease in herbivore insects by the 24,07% and an increase of predator species by the 19,48%. Also a decrease of weeds quantity, richness and biomass by approximately the 68%, 62% and 59% respectively has been recorded. Furthermore, the system is able to increase farms profit by the 10,33% compared to a traditional rice farming system.
Lastly, this method could improve soil quality, as a

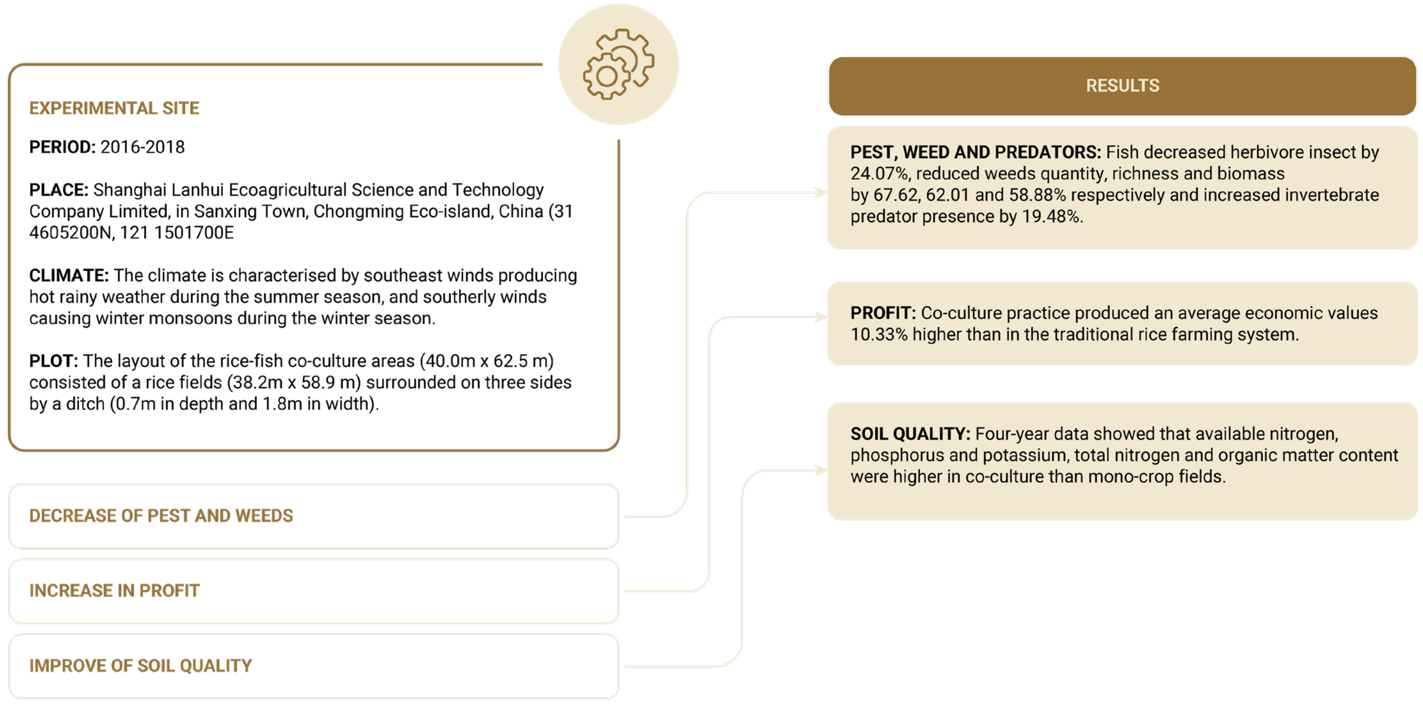
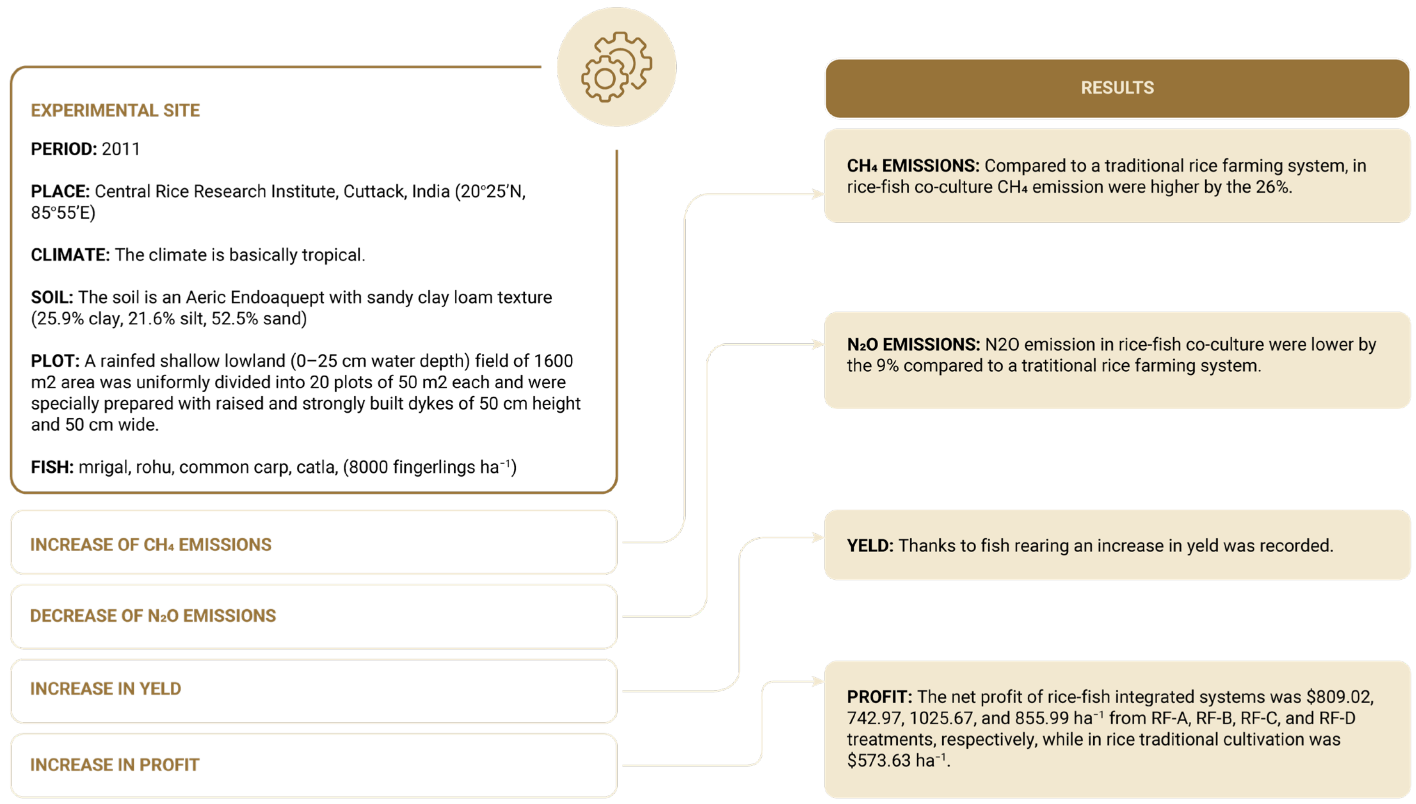


Fig.44 In the scheme, a summary is represented of a case study concerning rice-fish farming system (Wan, et al., 2019).

matter of fact, nitrogen, phosphorus, potassium and total nitrogen and organic matter content were higher after the introduction of fish in the paddy field chamber (Wan, et al., 2019).

A study from the Central Rice Research Institute in India (Figure 45) has proved that a rice-fish co-culture is able to decrease N_2O emission by the 9%, but at the same time it causes an increase in CH_4 emission by the 26%. Anyway, this system has other consequences such as an increase in yield thanks to fish rearing, and an increase of the net profit which differs by fish species (Bhattacharyya, et al., 2013).

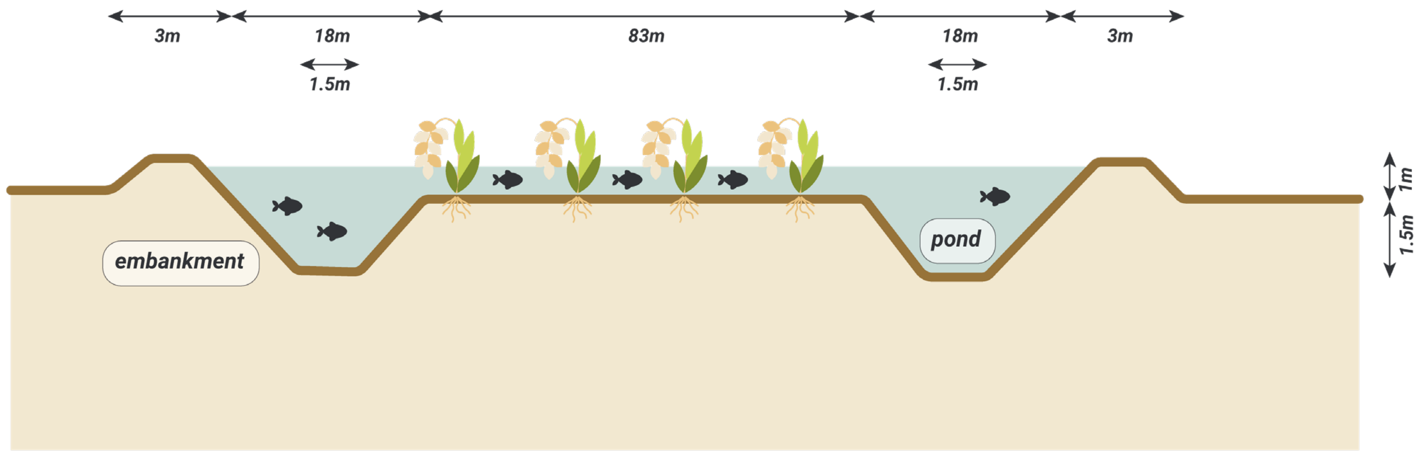


***CH_4:** Methane; **N_2O:** nitrous oxide; **RF-A:** Rice + Fish (mrigal, *C. mrigala* H.); **RF-B:** Rice + Fish (rohu, *L. rohita* H.); **RF-C:** Rice + Fish (common carp, *C. carpio* L.); **RF-D:** Rice + Fish (catla, *C. catla* H.)

Fig.45 In the scheme, a summary is represented of a case study concerning rice-fish farming system (Bhattacharyya, et al., 2013).

5.2.2
Field preparation for the introduction of fishes in rice cultivation

To introduce fish in the rice paddy chamber, some changes in the structure of the field are needed (Figure 46).
Here has been taken as a reference an Indian case study of the West Bengal State Fisheries Department. The project involves the construction of two ponds of 18 m width in the top and 1,5 m in the bottom, one at each side of the rice field chamber. Overall, the area of the ponds covers the 28% of the rice field area while the dikes about the 4,8%. Therefor a large area is reserved to fish, nevertheless farmers who adopted this system were able to get an annual harvest of about 102-122,5



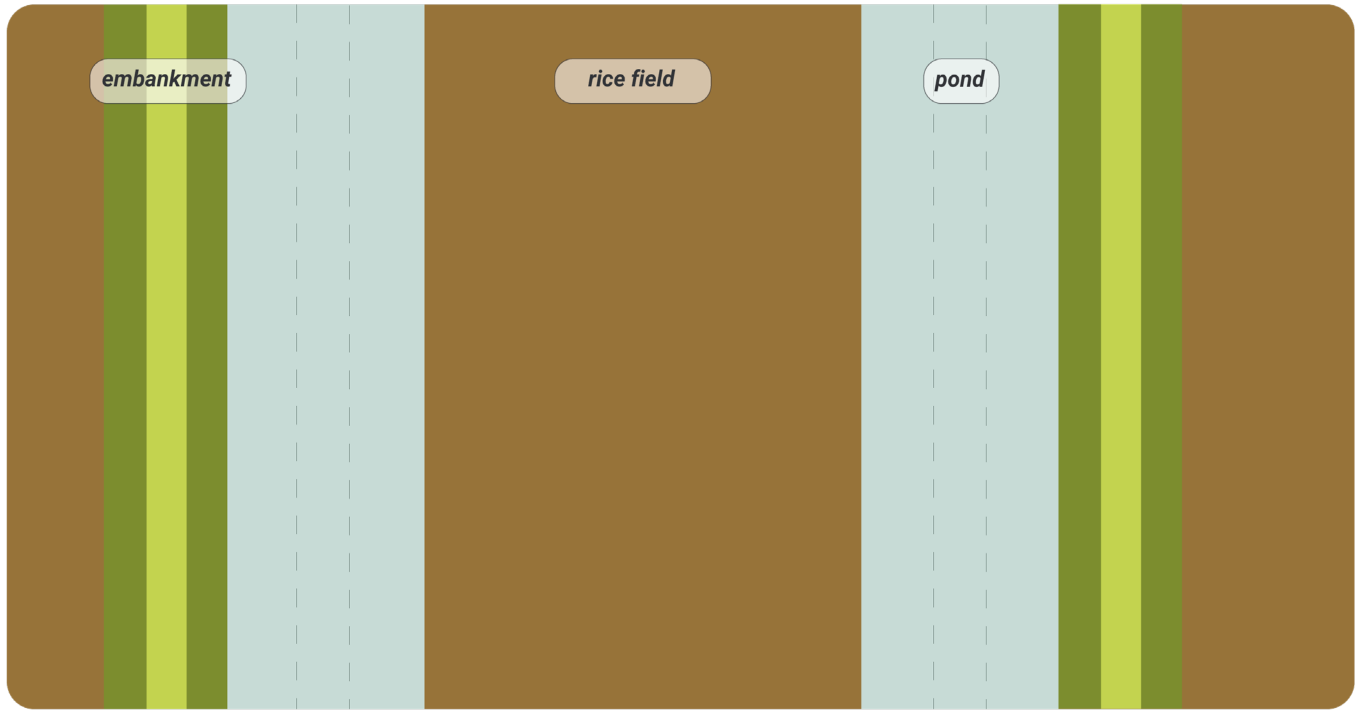


Fig.46 Rice-duck farming field construction (Halwart & Gupta, 2004)

quintals of rice per hectare.
To prevent fish from leaving the field area, panels are placed at the point where water exits the paddy field chamber and returns to the canal (Halwart & Gupta, 2004).

5.3 Rice-duck-fish farming

In order to introduce the topic of integrated rice duck and fish farming, a case study of the city of Dong in China, which has become the protection pilot of FAO's Globally Important Agricultural Heritage, is given below. Here, knowledge about this particular technique has been handed down for thousands of years. The fish are introduced into the paddy field after it is submerged at the beginning of the rice season, the ducks are inserted when the fish have reached about 8 cm in length (otherwise the ducks would eat them) and are removed when the rice is in bloom. The fish are removed just before harvest when the paddies are dried.
This system has brought many benefits to rice production such as the elimination of fertilisers and manure, and improved water and soil quality. In addition, Dong farmers have seen economic benefits, with productivity being three to four times higher than in a traditional farming system. Moreover, because the

Dong, L. (2019). FAO'S Cooperation with China on Poverty Reduction. China Today. http://www.chinatoday.com.cn/ctenglish/2018/tpxw/201903/t20190303_800158826.html

ducks and fish are organic products, they can be sold at twice the price of ordinary varieties. Finally, the work done by the ducks and fish in the paddy field reduces input costs (pesticides, fertilisers, feed and labour). Furthermore for Dong's people this system provides different services, such as food security, housing, social and cultural services, as well as improving the quality of life.
Then the co-culture of rice, fish and ducks provides also some environmental services, for instance it supports biodiversity, improve soil fertility by increasing certain nutrients such as nitrogen, phosphorus and potassium. Finally, raising fish and ducks in paddy fields can reduce emissions (Chinase Academy of Science, 2010).

5.3.1 Quantitative data

In order to provide clear evidence about the benefits of a system in which fish and ducks are integrated into rice cultivation, quantitative data were collected.
Therefore, the most relevant case studies can be found below, schematised in graphs as was done in the previous paragraphs for rice-duck and rice-fish farming.
In the upper left corner, the main characteristics of the case study can be found; below these, the benefits of the system are summarised, with the appropriate in-depth analysis.

A study conducted in India by Nayak, et al. (2018) showed some benefits from introducing ducks and fish into the paddy field chamber (Figure 47).
For example, it has been proven that compared to a traditional farming system, integrated farming (with fish and ducks) can improve some physical-chemical parameters of the water, for instance dissolved oxygen is increased by 8.4% and oxidation reduction potential is 31.8% higher.
Soil quality has also increased, due to an increase in soil nutrients, such as nitrogen, which has increased by 126%.
Finally, the whole system has also led to an improvement in the overall productivity of the paddy field, thanks to the sale of new food products (duck wax, fish meat and duck eggs).

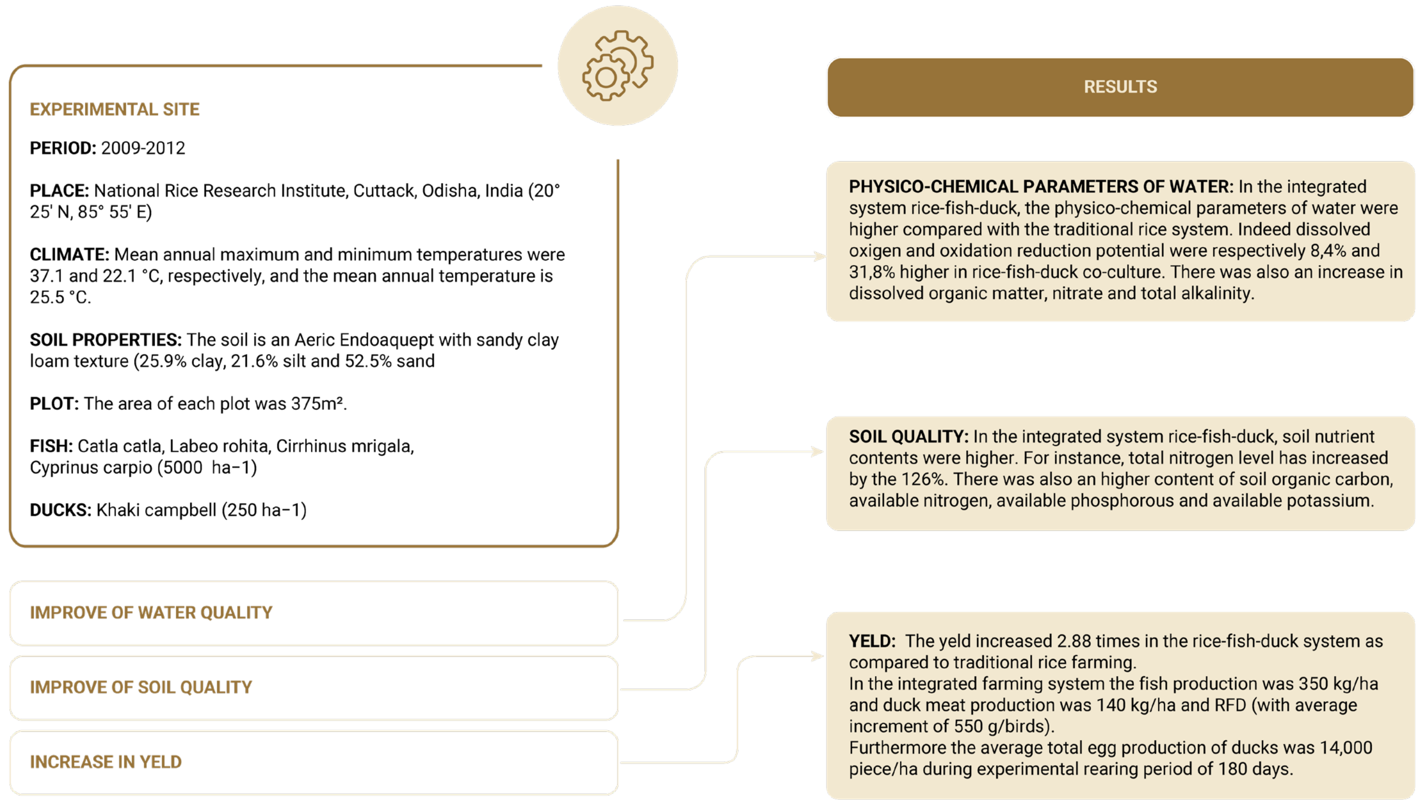


Fig.47 In the scheme, a summary is represented of a case study concerning rice-duck-fish farming system (Nayak, et al., 2018)

The experiment conducted by YUAN, et al. (2009) in China (Figure 48) shows that by integrating rice cultivation with duck and fish farming, the greenhouse effect cost can be decreased, as there is a reduction in CH_4 and N_2O emissions overall.
Furthermore, taking into account the environmental costs and the input and output costs, it can be stated that the introduction of fish and ducks into the paddy field chamber produces a greater economic benefit than traditional rice cultivation.

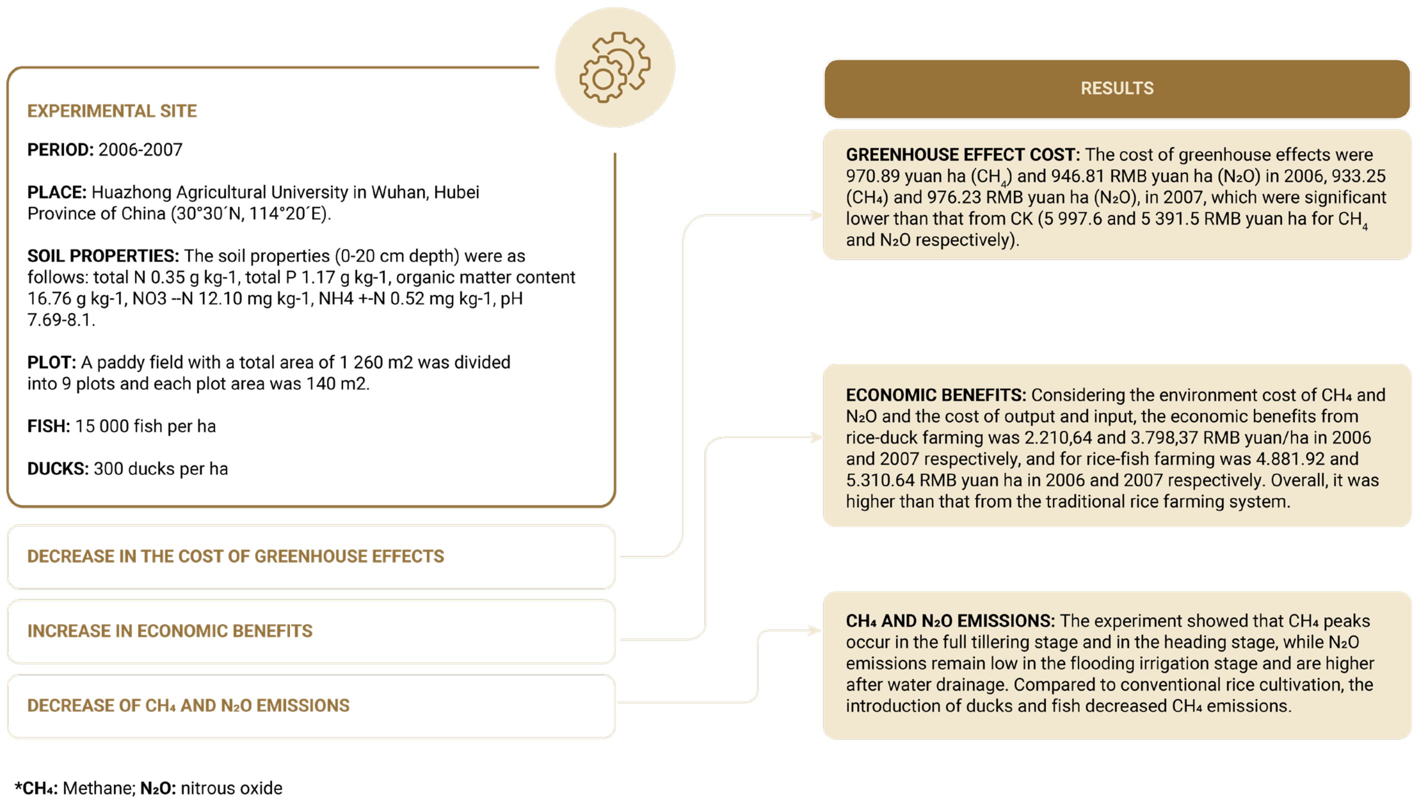


Fig.48 In the scheme, a summary is represented of a case study concerning rice-duck-fish farming system (YUAN, et al., 2009)

According to Zheng, et al. (2017) study (Figure 49), the integrated farming system in which ducks and fish are introduced into the paddy field chamber together has many advantages.
First of all, the use of pesticides and chemical fertilisers is reduced. Secondly, thanks to appropriate paddy field management, the economic benefits are much higher than other farming systems, partly due to an increase in productivity of 8 to 20%. It is also established that there is a 30% reduction in methane emissions while N2O emissions increase by 2%.
Finally, this study states that with the rice-duck-fish integrated farming system it is possible to reduce water use by 15-30% compared to integrated farming systems with only fish or ducks.

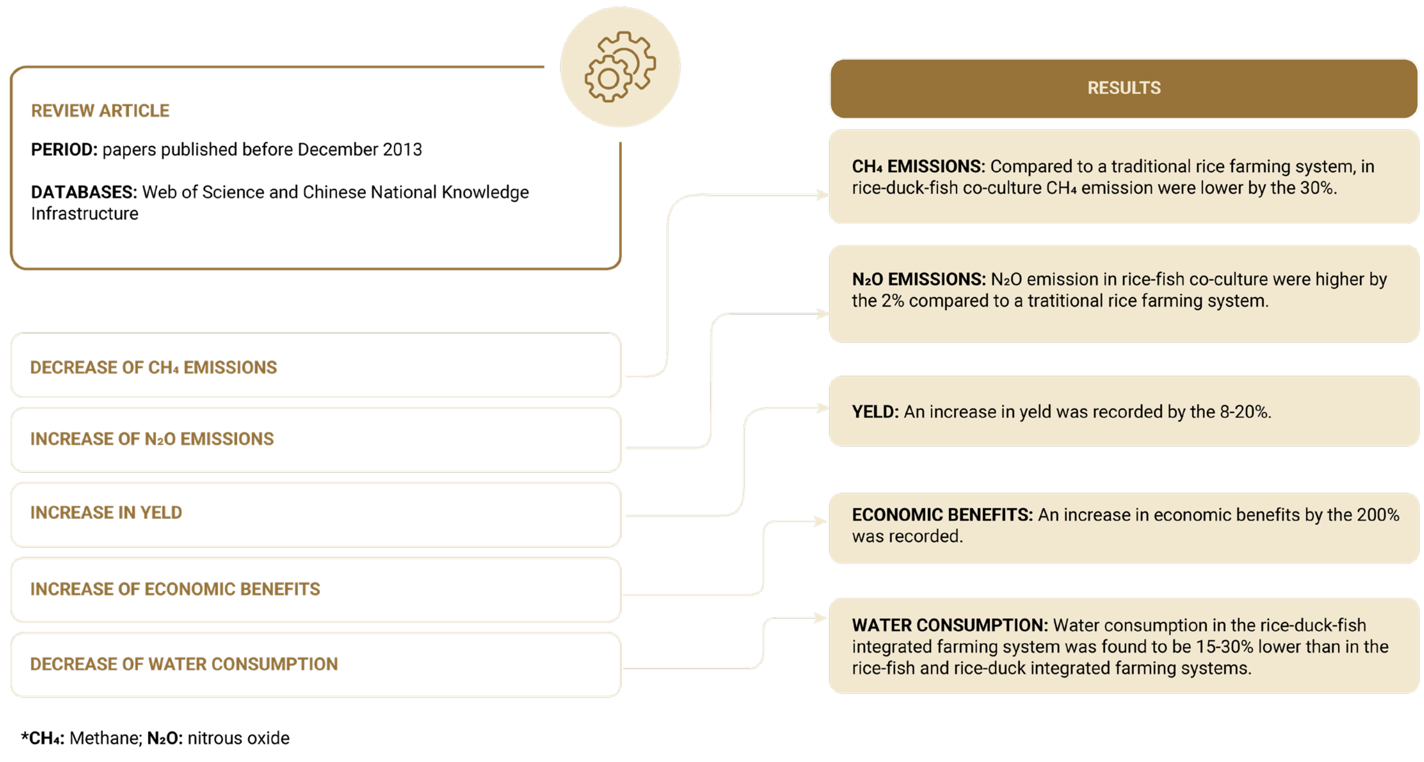


Fig.49 In the scheme, a summary is represented of a case study concerning rice-duck-fish farming system (Zheng, et al., 2017)

5.3.2
The rice-duck-fish system mechanism

To summarise, integrated agriculture provides numerous benefits, which have been listed in the above paragraphs with the appropriate quantitative data from some real case studies.
Below, the seven main benefits of the integrated rice-duck-fish system that emerged from this research will now be reported.
They will not be analysed from a quantitative point of view but rather explained.

In the integrated rice-duck-fish system it is possible to control weeds and pests without the use of chemicals. As two studies on rice-duck (Hossain, Sugimoto, Ahmed, & Islam, 2005) and rice-fish (Wan, et al., 2019) farming state, the two introduced farm animals feed on certain species that infest rice fields.

In particular, ducks decreased the presence of the green leafhopper, brown plant hopper, zigzag leaf hopper, rice bug, short-horned grasshopper, and long-horned grasshopper (insects' population). In addition, ducks eat weeds, such as *Echinocloa crusgalli, Scirpus mucronatus, Monochoria vaginalis* and *Fimbristylis miliaceae*, and their seeds.
Fish also feed on pests and weeds such as rice plant-hopper, rice leaf roller and rice stem borer.
The consequence of natural weed control is that the use of chemicals to combat them can be totally avoided. This represents a lower cost for the farm and a less polluted environment, avoiding soil and water contamination, as well as eliminating what is a threat to biodiversity.

The movement of the ducks and fish in the paddy field chamber helps to dissolve atmospheric oxygen in the water, also regular loading of faecal matters and movement of the soil in search of food contribute to improved soil nutrients as well as increasing the clay content.
The contribution of fish in particular is to improve nutrient availability as well as to increase root growth and the number of rice grains per seedling.
A positive effect on root growth is also produced by ducks, which also have a positive effect on plant biomass.
Through duck and fish excrement there is an increase in soil organic carbon, which plays a key role in enhancing soil fertility (Nayak, et al., 2018).

Studies have shown that introducing ducks and fish into the paddy field chamber can reduce emissions.
In particular, the bioturbation produced by the ducks increases the oxygen level in the water, and since they feed on weeds, insects and plankton, they do not allow them to consume the dissolved oxygen.
As oxygen availability increases, the oxidation of CH_4 by methanotrophs in the soil increases and consequently CH_4 emissions decrease.
On the contrary, N_2O emissions increase. This is due to an increase in dissolved oxygen, as a low oxygen content is required for N_2O consumption (Xu, Liu, Wang, Yu, & Hang, 2017).
On the other hand, fish increase the level of CH_4 because they decrease the level of dissolved oxygen, and their movement may lead to a release of CH_4 trapped in the soil, while, in contrast to ducks, fish decrease N_20 emissions (Bhattacharyya, et al., 2013).

Several studies reported in the previous paragraphs have stated that co-cultivation of rice, ducks and fish can lead to an increase in rice yield, more specifically the number of tillers and the number of grains per seedling seem to increase. This seems to be due to a decrease in rice plant diseases, weeds and pests, as well as the fact that cultivation takes place in a much healthier environment.

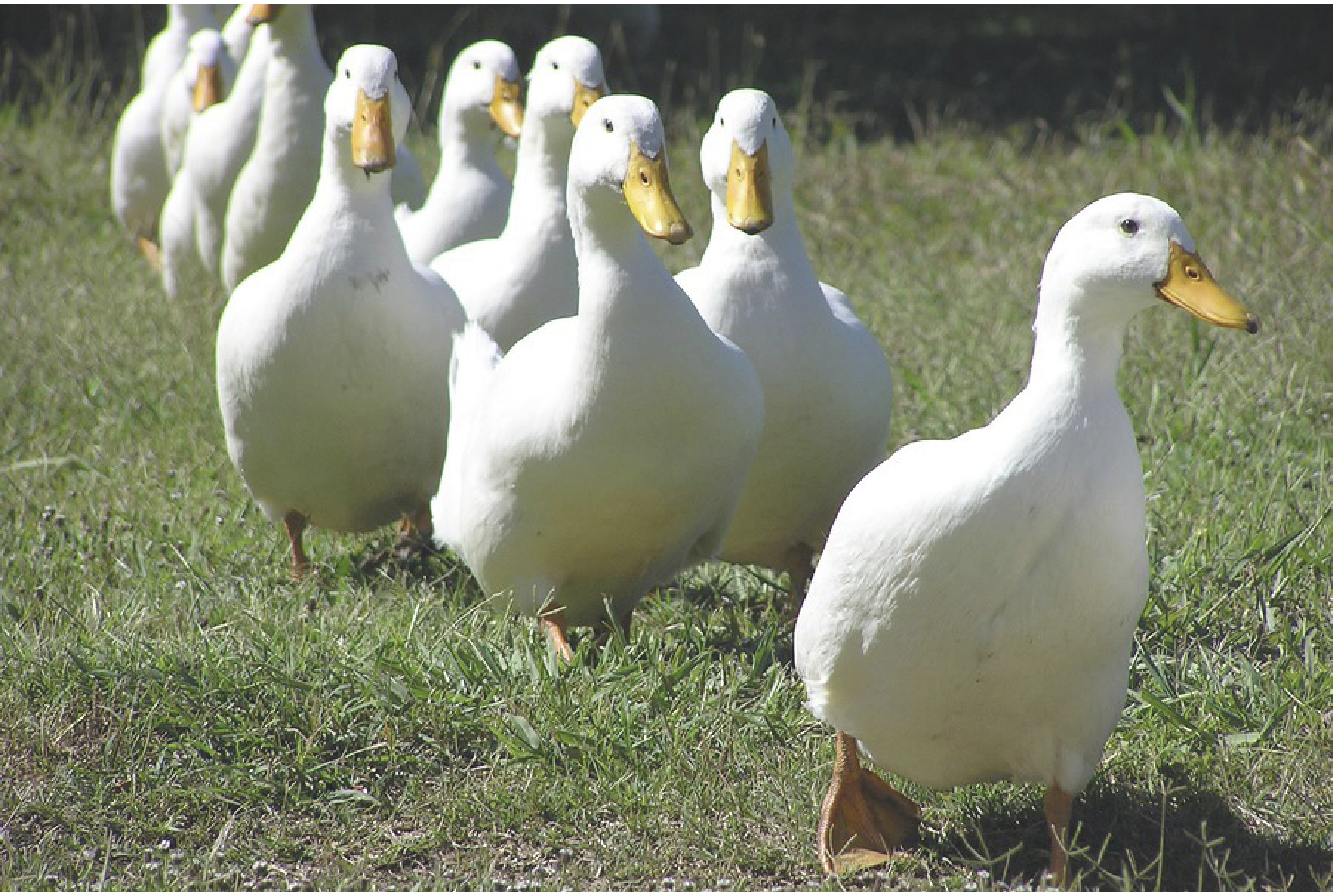
Finally, the introduction of breeding animals such as duck and fish into the paddy field leads to higher profits. This is due to the increase in saleable food products, duck meat, fish meat and duck eggs, as well as the increase in rice productivity, and savings on certain products such as fertilisers and pesticides.

Photo by Andrei Stratu on Unsplash

6.0 New system design

After learning about the company’s current situation and assessing its strengths and weaknesses, a strategy was chosen that could further improve the company’s already positive situation.
The strategy as seen in the previous chapter concerns the introduction of ducks and fish into the paddy field chamber.
It was chosen because of the numerous benefits it brings to the farm both from an environmental and economic point of view.
The first step that was taken to implement the new system was to choose the most suitable species of ducks and fish. The choice was made not only for reasons related to the characteristics that make them suitable for the paddy field ecosystem, but also based on the traditions of Piedmontese cuisine.
Subsequently, after learning from Asian case studies, where this practice is more widespread, the paddy field that will host them was redesigned so that it is adequately functional for rice, ducks and fish integrated farming practice.
Finally, all the action that have to be done to start the new activity were planned, and all the new costs and revenues were analysed in order to build the business plan.

6.1 Ducks



Purely Poultry. (2020, December 11). Grimaud Hybris Pekin Ducklings. https://www.purelypoultry.com/grimaud-hybrid-pekin-ducklings-p-1158.html

Peking ducks are one of the most common breeds of duck, this breed is used on farms for both meat and eggs.
Their origin is probably in South East Asia where they have also been domesticated for 2.000 years.
More precisely, this breed originated in China and has been exported since the end of the 19th century (The Happy Chicken Coop, 2020).

There are currently two types of Peking duck, the American and the German.
It is considered by breeders to be the best meat breed, and because of its speed in growing (ducklings weigh 2.5kg at eight weeks old) it is suitable for intensive farming, but it is also a good laying bird, producing around 130-150 eggs per year.
Another characteristic of this breed is that it cannot fly. The average weight they reach is 3.5 kg for males and 3 kg for females (Agraria.org, n.d.) (Cepollini, 2014).
The most suitable habitat for this type of duck is wetland, a water-rich environment. In fact, these ducks were originally bred in rice fields in China.
They can withstand both very high and very low temperatures, but especially in winter they need a shelter.
The diet of the Peking duck is varied. In the wild they feed mainly on aquatic organisms such as fish, algae and frogs, or even nuts and seeds or worms, crickets,

Fig.50 In the scheme, a summary is represented of Pekin ducks' characteristics (Runner, 2021) (Cornell University College of Veterinary Medicine,n.d.)

HABITAT

The Pekin duck is a domesticated duck used primarily for egg and meat production. It was bred from the Mallard in China. This ducks are hardy creatures and can survive extreme hot and cold temperatures. In the winter, they need a draft-free shelter with hay on the floor. In the summer, they need shade and extra water.

FOOD PRODUCT

Meat and eggs

DIET

In the wild, depending on the time of year and location, ducks eat a wide variety of things. In the wild, ducks eat many aquatic organisms like fish, frogs, and algae. They also forage for nuts, berries, seeds, worms, crickets, flies, and mosquitos are also on the menu.

AVERAGE WEIGHT

3-3,5 kg

REPRODUCTIVE CYCLE

For every 5 females that are mated, one male must be present to ensure the desired result. A female Pekin begins to lay eggs between November and December. Pekin duck embryos take around 28 days to develop in the egg at 99.5°F (37.5°C) and 55-75% humidity. The eggs will hatch after about 1 month, and from that time the ducklings' growth will be rapid, so much so that by the time they are four months old, they will reach 1,8 kg in weight.

SELLING PRICE

10 €/kg

flies and mosquitoes.
In order to breed successfully, there must be 5 female ducks for every male.
Peking ducks are not good hatchers, despite their high egg production, so it may be necessary to purchase incubators.
The eggs then take about twenty-eight days to hatch (Runner, 2021) (Il Verde Mondo, 2016).
The temperature in the incubator should be 37.5°C and the humidity 55% (Cornell University College of Veterinary Medicine, n.d.).

Duck meat is also used in traditional Piedmontese cuisine.
In fact, a typical dish from this region is "Anatra farcita alla piemontese".
This dish consists of stuffing the duck with a filling of mixed meat, bacon and pork sausage, onion, rice, garlic, parsley, eggs, nutmeg, salt and pepper.
The first step in cooking is to brown the duck, after adding oil and rosemary, and then simmer it with brandy.
Secondly, the meat stock is added, after which it must cook in the oven for two hours (Original Italy, n.d.).

Donnamoderna. (2014, Settembre 9). Anatra farcita alla piemontese. https://ricette.donnamoderna.com/anatra-farcita-alla-piemontese

6.2 Fish

Wikipedia. (2021, February 5). Tinca tinca. https://it.wikipedia.org/wiki/Tinca_tinca

The tench (*Tinca tinca*), is a cyprinid and is widespread in much of Europe and Asia.
It is mainly found in still or slow-flowing waters with a soft clayey or muddy substrate such as ponds, marshes, ditches, lakes, canals etc.
The optimum water temperature for this species is between 15 and 23,5 °C, but it can also tolerate higher temperatures, up to 37 °C, for short periods, temperature fluctuations and it can also tolerate waters lacking in oxygen.
It feeds mainly at night, and studies carried out in a lagoon in Iran on the stomachs of tench have identified 17 main types of food, including odonates,

snails, aquatic macrophytes, trichoptera, chironomids, hemipterans, ephemeroptera, fry, plant seeds, zooplankton, phytoplankton, etc.
Tench can reach a length of 70 cm and a weight of 7,5 kg, but the average size is 20-40 cm and the weight varies from 600 g to 2 kg.
As far as reproduction is concerned, males reach sexual maturity at two years of age and females at 3-4 years. The female lays her eggs in small groups, followed by two males that fertilise the eggs; on average, one female releases three hundred thousand eggs per season. Hatching usually occurs after 4-8 days and the doubling time of the population ranges from 1,4 to 4,4 years.
The market price of tench varies from 15 to 20 euros per kg (Porcellotti, n.d.) (Pescare.biz, 2018).

Fig.51 In the scheme, a summary is represented of Tench's characteristics (Porcellotti, n.d.)

HABITAT

The tench is widespread in still or slow-flowing waters, rich in submerged vegetation, with soft substrate and exposed to relatively high summer temperatures. It inhabits ponds, marshes, ditches, lakes (including hilly or mountainous ones), canals, streams, rivers, and spring waters.
The strong resistance to temperature changes allows an easy acclimatization in different water basins. It can tolerate, if necessary, oxygen deficiencies.

DIET

Omnivorous species, with diet composition varying according to season, age, and sex. Tench is most likely primarily carnivorous. Generally the diet includes insects, crustaceans, molluscs, worms, algae, aquatic macrophytes and organic detritus, the highest percentages are represented by phytoplankton, snails and hemipterans, constituting respectively 68.5%, 65.7% and 34.0% of the total diet.

REPRODUCTIVE CYCLE

Minimum population doubling time, average: 1.4-4.4 years (tm=2; tmax=7; Fec=120,000-800,000).According to the population and the trophic characteristics of the environment, sexual maturity is reached between 2 and 6 years, when the specimens have a size between 70 and 250 mm, usually the males mature a year before the females. The spawning in Italy generally begins in May, the fecundity is high, females weighing a couple of kilograms can produce up to three hundred thousand eggs in optimal conditions the hatching occurs in 4-8 days.

FOOD PRODUCT

Meat

AVERAGE SIZE AND WEIGHT

20-40 cm
600 g-2 kg

SELLING PRICE

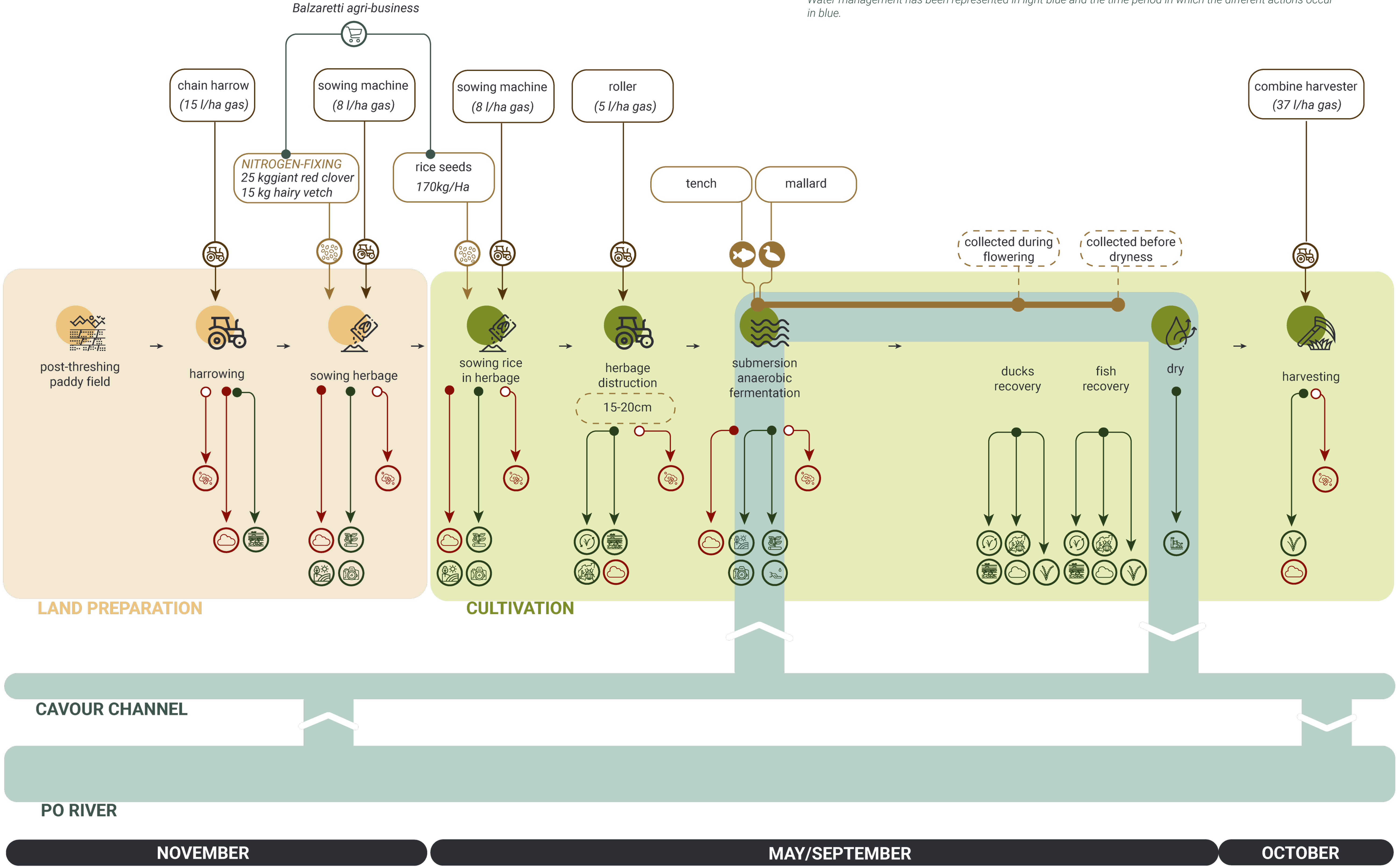
20 €/kg

Furthermore, in the Piedmont region, more precisely in the provinces of Turin, Asti and Cuneo, a particular species of tench is bred: Tinca Gobba Dorata del Pianalto di Poirino DOP.
In these areas, this particular type of tench was first bred in the second half of the eighteenth century, when some families managed to earn money from the sale of tench, and today this fish represents an important economic resource for the area.
The Tinca Gobba Dorata del Pianalto di Poirino PDO can be recognised by the bright grey-graphite or opaline green skin colour on the back, while the sides are golden yellow.
The traditional Piedmontese recipe for preparing tench is to fry the fish without flouring it.
Then the tench is left to rest for five days in the refrigerator with a dressing of onion, garlic, carrot, herbs, oil, salt, pepper, vinegar and water.
Before serving, they should be drained (Piemonteagri, n.d.) (Qualigeo, n.d.).

Iannello, A. (2019, January 10). La Tinca Gobba Dorata: dal carpione alle proposte gourmet. Agrodolce. https://www.agrodolce.it/2018/06/28/la-tinca-gobba-dorata-dal-carpione-alle-proposte-gourmet/

6.3
New cultivation system

Fig.52 In the scheme, the new cultivation system is represented. In the upper part the inputs are represented, in order in the first place is the origin of the products used for cultivation, in the band below are listed the agricultural machinery used and the consumption of gas oil (l/ha) that they involve (Regione Piemonte, 2016). Below are the material inputs, which correspond to fertilizers, herbicides, ducks, fish and seeds. The timeline shows all the steps of cultivation and below it are listed the outputs as ecosystem services. In red are indicated the risks while in green are represented the beneficial services that the paddy field provides. Water management has been represented in light blue and the time period in which the different actions occur in blue.



The cultivation system that will be implemented with the introduction of ducks and fish is green mulching. Submergence in this type of process takes place after the felling of the grassland, between the months of May and June. It is at this point that ducks and fish will be introduced into the paddy field, and will be left free in the flooded paddy field chamber for the entire rice-growing season.
The ducks will be collected during the rice flowering period, otherwise they could eat it, while the fish will be collected just before the paddy field is dried for harvesting (Chinase Academy of Science, 2010).

6.4 Field construction

An area of 4,953 ha (Fig.53), which corresponds to one of the paddy chambers owned by the farm, was considered as a pilot project.
To accommodate ducks and fish it is necessary to have a permanent source of water, so it was planned to construct two gullies on either side of the paddy field chamber one metre deep and one metre wide, and a pond at one end of the field for a total of 1 ha of area covered by water permanently.
To prevent fish from leaving the pilot project area, a net must be placed at the end of each ditch to prevent them from entering the common channel leading to other fields.
For the ducks, the construction of a shelter for the night and the purchase of a hatchery is necessary, as female pekin ducks are not good hatchers.
Finally, to prevent the ducks from going to other fields, it is necessary to surround the area involved with a fence.

The regulations state that the maximum number of tench that can be farmed is 5.000 tench/ha, which corresponds to the number of tench that can be housed in the area covered by water permanently, but for the initial phase of the project it was decided to include 500 of them (Senato della Repubblica, 2021).
For ducks, on the other hand, the regulations state that the maximum amount of nitrogen that can be emitted from the farm is 170 kg/N/ha/year, since ducks produce 240 kg/t (live weight) of nitrogen per year and therefore one produces 0.96 kg/N/year, the maximum number of ducks per hectare (outdoor) is 177 (Ferrucci & Marcone, 2017) (Consiglio regionale del Piemonte, 2020).
For indoor space (shelter), the standards provide for a maximum of 21 kg liveweight of ducks per m², which corresponds to 5 ducks per m² (Commissione Europea, 2020).
It was decided to build a 118 m² shelter which can therefore accommodate a maximum of 590 ducks.
In order to leave a margin for population growth to avoid exceeding the limit, it was decided to host a maximum of 168 ducks during the winter when the space covered by water is 1 ha while in the summer the duck population can reach 354 (3 ducks/ha), taking into account the capacity limit of the refuge.

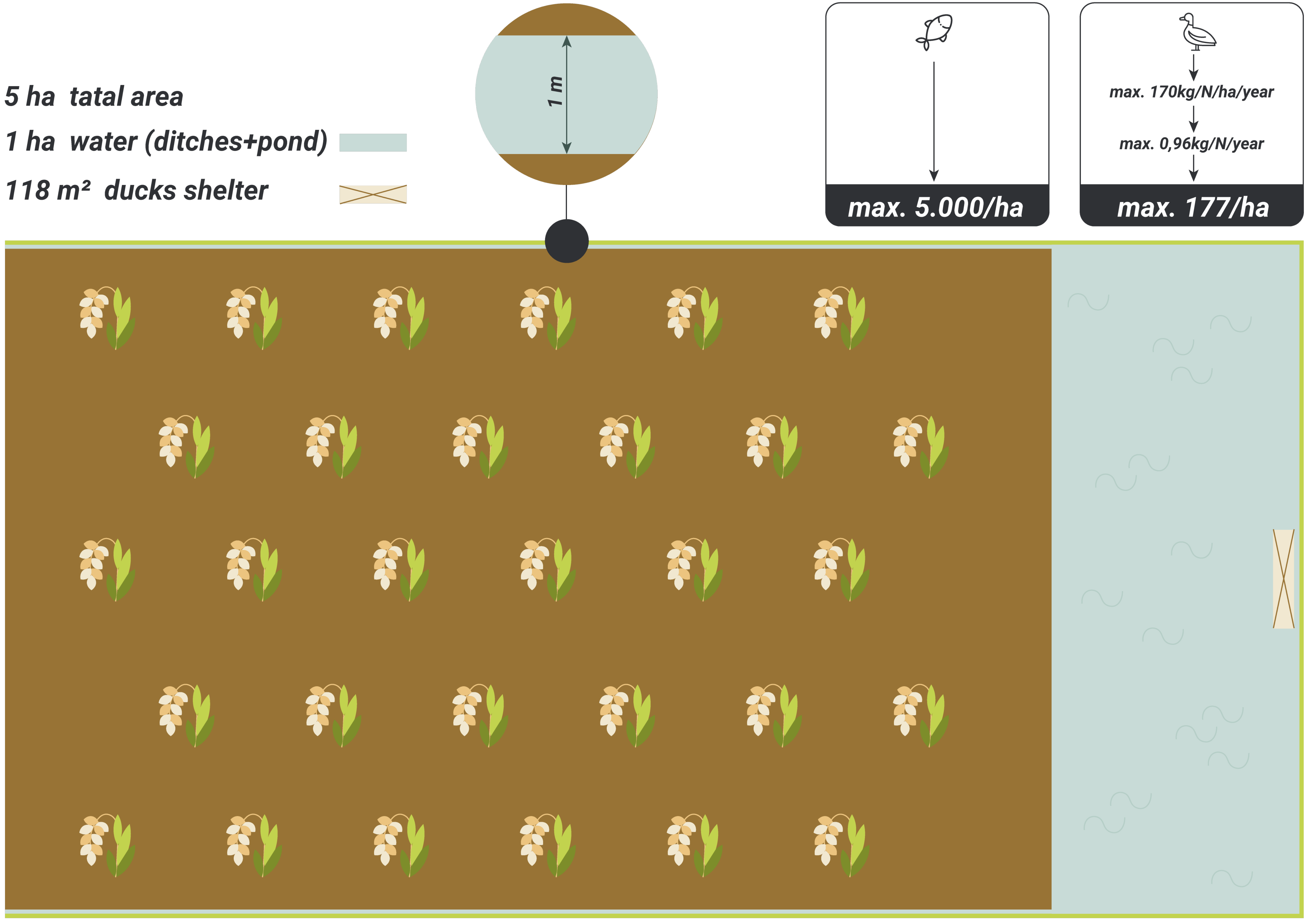


Fig.53 The figure shows the map of the paddy field chamber used for the pilot project, with the modifications made for the introduction of ducks and fish. The arable land is shown in brown, the areas permanently covered with water in blue and the duck refuge in pink.

6.5
New system management

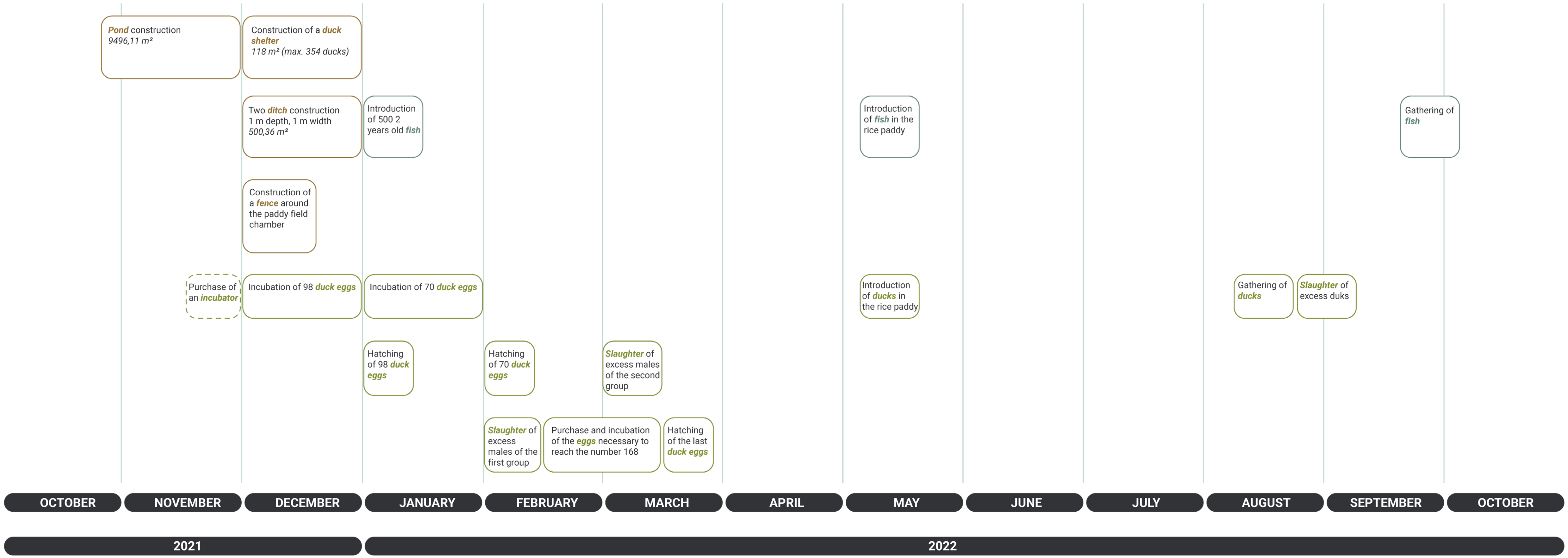


Fig.54 the diagram shows all the activities necessary for the start of the new business with the corresponding timeframe.

As can be seen in Figure 54, the activities related to the new project begin after the harvest, at the end of October.
The first thing to do will be to dig the pond, and once the space has been created, the construction of the duck shelter can continue.
At the same time, and immediately after digging the pond, the two side ditches will have to be dug.
During the same period, the installation of the duck fence is planned, as well as the purchase of an incubator and 98 duck eggs which will be promptly placed in the incubator. After one month, the eggs will hatch and the remaining 70 eggs will be incubated, resulting in 168 ducks, which is the number of ducks expected during the winter.
At the same time, 500 two-year-old fish will be purchased, which can be added after the pond and ditches have been dug and submerged.
The second battery of duck eggs will be incubated and at one month of age the ducks from the first battery will be ready for the first skimming. In fact, since for each male there must be five females, it may be necessary

to proceed with the slaughter of a few male ducks, thus receiving the first gains. It was chosen to buy duck eggs and not ducklings because of the lower cost, and because in any case it is not possible to choose the sex of the ducklings when purchasing them.
At this point it may be necessary to purchase additional eggs to reach the set number. This should be repeated in the first month of life of the ducks in the second battery.
In May, after the rice field has been submerged, the ducks and fish will be able to occupy all 5 hectares of the field used for the pilot project. During this period, the ducks also begin to reproduce, and during the rice season they can reach a number of 354 individuals, although it is important to ensure that there is always the right proportion of males to females.
At the time of the rice flowering the ducks must be collected and then the excess number of ducks must be slaughtered in order to comply with the regulations.
Before the rice chamber is dried out, the fish must be moved back into the area where the water is permanently present.
As for the fish, at two years of age (the age at which they will be purchased) they will weigh between 100 and 200 g and may already be fished.

6.6 New costs and revenues

All the activities that need to be carried out to start the new business involve new costs for the company so, in order to establish overall investment for the implementation of the project proposal, costs have been defined based on the price list for agriculture provided by the Piedmont Region (Regione Piemonte, 2021) and on the analysis of local market, as shown in Figure 55.

EXPENCES	QUANTITY	TOTAL COST
Pond construction	1	25.246
Ditch construction	2	1.330
Duck's shelter	1	1.900
Fence	1	2.856
Incubator	1	140
Duck eggs	168	487,2
Tench	500	900
Nets for the channel drain	2	28,90

Fig.55 Expences list for the system implementation

In addition to new costs, the new activity will bring new income as shown in Figure 56. These come from the new food products that can be sold, such as duck meat, fish meat and duck eggs, but also from the increased productivity of rice.

NEW SALEABLE PRODUCTS	MARKET PRICE
Duck meat	10 €/kg
Fish meat	20 €/kg
Duck eggs	0,50 €/egg

Fig.56 New earnings from the rice-fish-duck integrated system

To quantify the revenue from the food products, an assumption has been made based on other studies.
As said before integrated agriculture could bring an increase in revenues by about the 50% (Halwart & Gupta, 2004) (Hossain, Sugimoto, Ahmed, & Islam, 2005). Therefore, in order to have a more complete assumption, data from the pilot project were compared (Fig.57) with data from a similar Indian study (Nayak, et al., 2018) in which fish and ducks were integrated into the paddy field.
The results made it possible to obtain more precise quantitative data on saleable food products.
In fact, in one year it will be possible to sell about 198,12 kg of duck meat, 35 kg of fish meat and 3.976 eggs.

DUCK MEAT	FISH MEAT	DUCK EGGS
250 ducks/ha	5.000 fish/ha	250 ducks/ha
140 kg/ha/year	350 kg/ha/year	14.000 eggs/year
71 ducks/ha	101 fish/ha	71 ducks/ha
40 kg/ha/year	7 kg/ha/year	
198,12 kg/year	35 kg/year	3.976 eggs/year

Nayak, et al. (2018)
Pilot project

Fig.57 Comparison with data from an Indian case study to obtain assumptions about the amount of fish and duck meat and duck eggs to be sold in a year (Nayak, et al., 2018)

Once the quantity of products that could be sold in a year was known, the annual profit was calculated based on the market price of each good, as can be seen in Figure 58.
For rice, an increase of 29% was calculated on the biological rice production of the pilot project, the percentage was obtained from an average of data collected in some of the case studies mentioned in chapter 5.0.
Adding up the revenues obtained from the different goods the total is 34.000 € which corresponds to the total revenues given by the pilot project.

Fig.58 Assumption of revenue obtained in one year from food products sold by the company

RICE	**+29%**	**29.300 €/year**
FISH MEAT	**20 €/kg**	**700 €/year**
DUCKS MEAT	**10 €/kg**	**2.000 €/year**
DUCKS EGGS	**0,50 €/piece**	**2.000 €/year**

6.7 Business plan

All the additional expenses planned for the new system implementation have been added to a five years business plan which is shown in Figure 57.
In year zero, the initial balance sheet of the company was reported as a reference to compare it with the data of the new project.
Year 1 is the year in which work begins for the start of the activity in October after the harvest, so the income on rice will be the same as the previous year, but there will be some extra expenses due to the new business.
At the beginning of year 2 the last purchases will be made, and this is the year when the breeding activity actually starts. Consequently, in this year the first earnings from duck and fish breeding are obtained.
Also in year 2, an employee will be hired to manage the breeding business, which will cost the company 16.000 € per year.
From year 3 the expenses due to the implementation of the new activity will decrease, but a sum has been assumed to cover periodic maintenance work.
All costs can be viewed under the heading: "Current liabilitis". Earnings, on the other hand, can be found under "Current assets" and are divided into "Trade receivables" and "Financing".
Under Trade receivables from year 2 onwards, new earnings were added.
In fact, according to the hypothesis made in the previous paragraph, 34.000 €, corresponding to the earnings from the pilot project, were added to the company's total income.
The project can also receive some founding from Piedmont Region, as a matter of fact the cost of the construction of the two ditches and the pond could be covered by the measure 04.4.01 of Rural Development Plan, which covers the entire cost, as it is part of the actions aimed at restoring wetlands by converting agricultural land into semi-natural areas. And for the maintenance of this kind of areas 1.000 €/ha/year for ten years are provided.
The farm can also receive funding for the conversion of the field from conventional to biological. As year 0 is the first year of biological farming, the farm can get 600 €/

ha/year for two more years, after which 450 €/ha/year are provided.
Conversion of the field to integrated agriculture, for the first 5 years, is financed with 210 €/ha/year.
Finally, the farm can also receive 100 €/ha for winter herbage (Regione Piemonte, 2020).

Fig.59 In the scheme a simplified version of the five years business plan is reported

BUSINESS PLAN	Year 0	Year 1	Year 2	Year 3	Year 4
ASSET					
NON CURRENT ASSETS		**19.900**	**19.800**	**19.700**	**19.600**
TANGIBLE ASSETS		19.900	19.800	19.700	19.600
Land and buildings		19.900	19.800	19.700	19.600
net book value last year			19.900	19.800	19.700
investment current year		20.000			
depreciation		100	100	100	100
CURRENT ASSETS	**123.738**	**164.199**	**301.551**	**416.876**	**532.201**
TRADE RECEIVABLES					
cashing	191.087	191.087	225.151	225.151	225.151
revenue	191.087	191.087	225.151	225.151	225.151
FINANCING					
cashing	39.000	2.972	31.093	8.222	8.222
revenue	39.000	2.972	31.093	8.222	8.222
CASH AND CASH EQUIVALENT	**123.738**	**164.199**	**301.551**	**416.876**	**532.201**
Total assets	***123.738***	***184.099***	***321.351***	***436.576***	***551.801***
LIABILITIES					
EQUITY	**123.737**	**184.097**	**321.349**	**436.574**	**551.799**
RESERVES AND RETURN EARNING		123.737	184.097	321.349	436.574
INCOME (LOSS) OF THE PERIOD	123.737	60.360	137.252	115.225	115.225
CURRENT LIABILITIES					
SHORT-TERM DEBT					
Debt from suppliers for operating activities					
payment	56.026	87.233	56.527	55.683	55.683
cost	56.026	87.233	56.527	55.683	55.683
Debt from personell debt					
payment			16.000	16.000	16.000
cost			16.000	16.000	16.000
Debt from suppliers for general administrative expenses					
payment	13.959	10.000	10.000	10.000	10.000
cost	13.959	10.000	10.000	10.000	10.000
Debt from suppliers for raw material and finished goods					
Increase in raw material and finished goods	36.364	36.364	36.364	36.364	36.364
Decrease in raw material and finished goods	36.364	36.364	36.364	36.364	36.364
payment	36.364	36.364	36.364	36.364	36.364
CURRENT PORTION OF LONG-TERM DEBT					
From investing activities					
payment		20.000			
cost		20.000			
Total liabilities + shareholders' equity	***123.737***	***184.097***	***321.349***	***436.574***	***551.799***

To see how much the new integrated farming system has actually brought economic benefits to the company, it is useful to focus on EBITDA (Earnings Before Interests Taxes Depreciation & Amortisation), where earnings without the influence of financing can be seen. As shown in Figure 58, in year 0 the earnings are €84.738, whereas two years after the launch of the system, in year 4, the earnings will be €107.103. Year 1 will be the year with the lowest earnings because the costs of starting the new activity will be faced but no earnings will be obtained from it yet.

Fig.60 In the scheme the profit and loss table is represented

PROFIT & LOSS	Year 0	Year 1	Year 2	Year 3	Year 4
Sales and services revenue	191.087	191.087	225.151	225.151	225.151
Cost of sales	36.364	36.364	36.364	36.364	36.364
Gross profit	154.723	154.723	188.786	188.786	188.786
General administrative expenses	13.959	10.000	10.000	10.000	10.000
Total operating expenses	13.959	10.000	10.000	10.000	10.000
Salaries and wages			16.000	16.000	16.000
Suppliers	56.026	87.233	56.527	55.683	55.683
EBITDA	84.738	57.489	106.259	107.103	107.103
Depreciation		100	100	100	100
EBIT	84.738	57.389	106.159	107.003	107.003
Financing	39.000	2.972	31.093	8.222	8.222
Profit before taxes	123.738	60.361	137.252	115.225	115.225
Net result	123.738	60.361	137.252	115.225	115.225

CASH FLOW	2020	2021	2022	2023	2024
Cash and cash equicalent at initial of period		123.738	164.199	301.551	416.876
Net cash from operating activities	84.738	57.489	106.259	107.103	107.103
Cash used in investing of tangible and intagible assets		20.000			
Cash and cash equicalent before financing	84.738	161.227	270.458	408.654	523.979
Financing	39.000	2.972	31.093	8.222	8.222
Cash and cash equivalents at the end of the period	123.738	164.199	301.551	416.876	532.201

Fig.61 In the scheme the cash flow table is represented

So to summarise, the introduction of ducks and fish into the paddy field, as we have seen, brings economic benefits to the farm which derive from the earnings for the new saleable food products, but also from the cost reduction generated by integrated agriculture.
As shown in Figure 60, costs for fertilizer and weeding are eliminated while there is a decrease in costs for gas and water (compared with the conventional cultivation), by contrast costs for maintenance are higher.

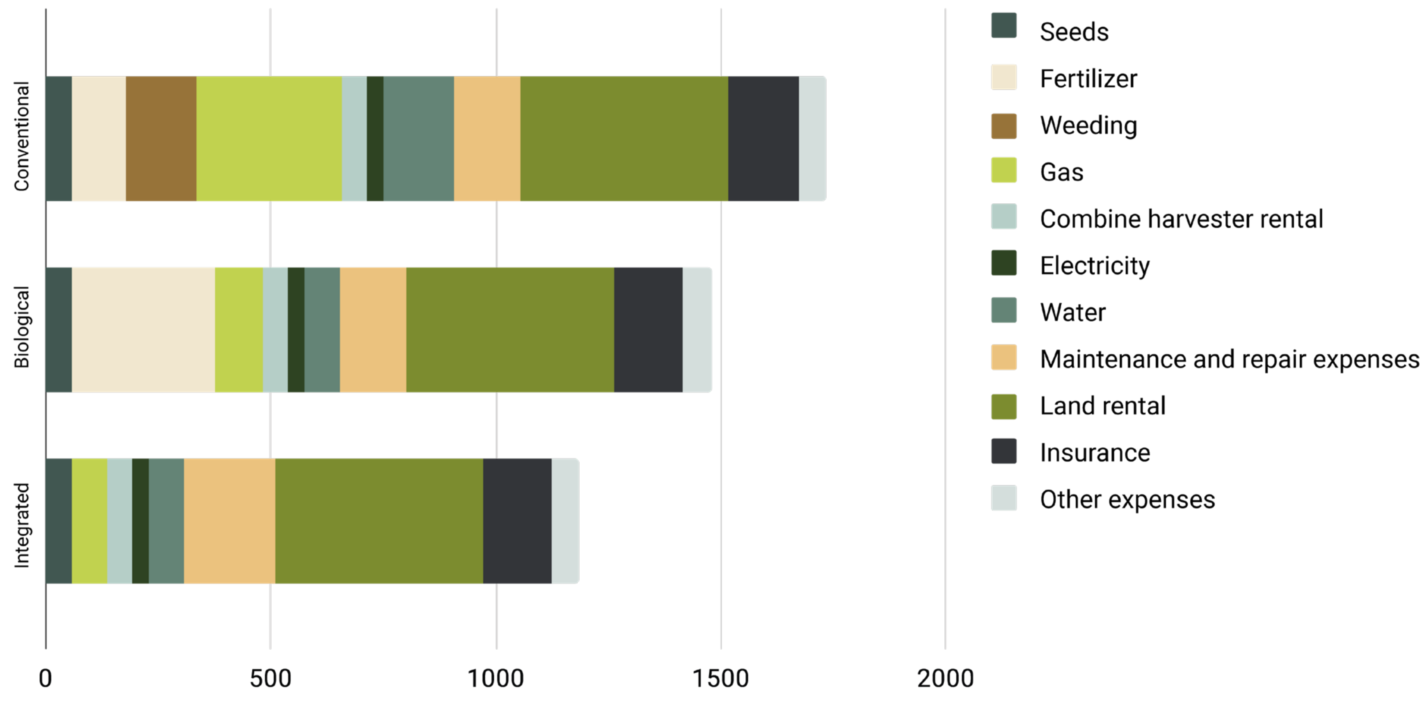


Fig.62 In the scheme the comparison between conventional, biological, integrated agriculture costs is represented

6.8
From linear to systemic

As shown by the analysis of the rice agro-ecosystem (where a conventional cultivation technique is used), there are several damages that are caused by profit-maximising processes.
As can be seen in the summary diagram (Figure 61) the use of chemicals such as fertilisers and herbicides produce a service, in other words the fertiliser provides nutrients to the soil, while pesticides and herbicides control weeds and pests. However, these services have a negative impact on the surrounding environment: they affect biodiversity by damaging the habitat that the paddy field produces for many species, they threaten the quality of the rice and finally they contaminate the soil and the water that floods the paddy field and consequently that of the canal.
Biodiversity is also put at risk by the invasive cultivation techniques used to make production more efficient. In fact, the assiduous presence of man due to constant

tilling of the field and the use of certain machines make it impossible for some species to survive. For example, the laser levelling machine prevents the creation of small permanent water pools in the field, which, during dry periods, allowed some species, such as odonates, to complete their life cycle. In addition, the proliferation of mosquitoes is allowed by hindering the development of species such as odonates, which are predators of mosquito larvae.
The development of the project, which consists of introducing ducks and fish into the paddy field chamber, results in a system that is capable of regulating itself with minimal human interference and that brings numerous benefits to the ecosystem.
As shown in Figure 62, the introduction of ducks and fish provides various ecosystem services. First of all, they enrich the soil with nutrients, making it more fertile without the use of chemicals.
In addition, these species feed on weeds and pests that infest rice plants, thus creating a healthier environment that helps rice quality and productivity, as well as avoiding the use of pesticides and herbicides.
The result will be an environment free of contamination from the use of chemicals, thus enhancing the quality of the rice ecosystem and consequently of the final product, rice.
These aspects create the ideal conditions for the creation of habitats and consequently for the increase in biodiversity, which in turn contributes to the uniqueness of the rice landscape and gives the opportunity to implement educational activities such as birdwatching and to promote ecotourism.
Lastly, as seen above, rice paddies produce N_2O and CH_4 emissions, but ducks and fish are able to regulate them through their activity.
In conclusion, the rice agro-ecosystem has been significantly improved by the implementation of integrated agriculture.

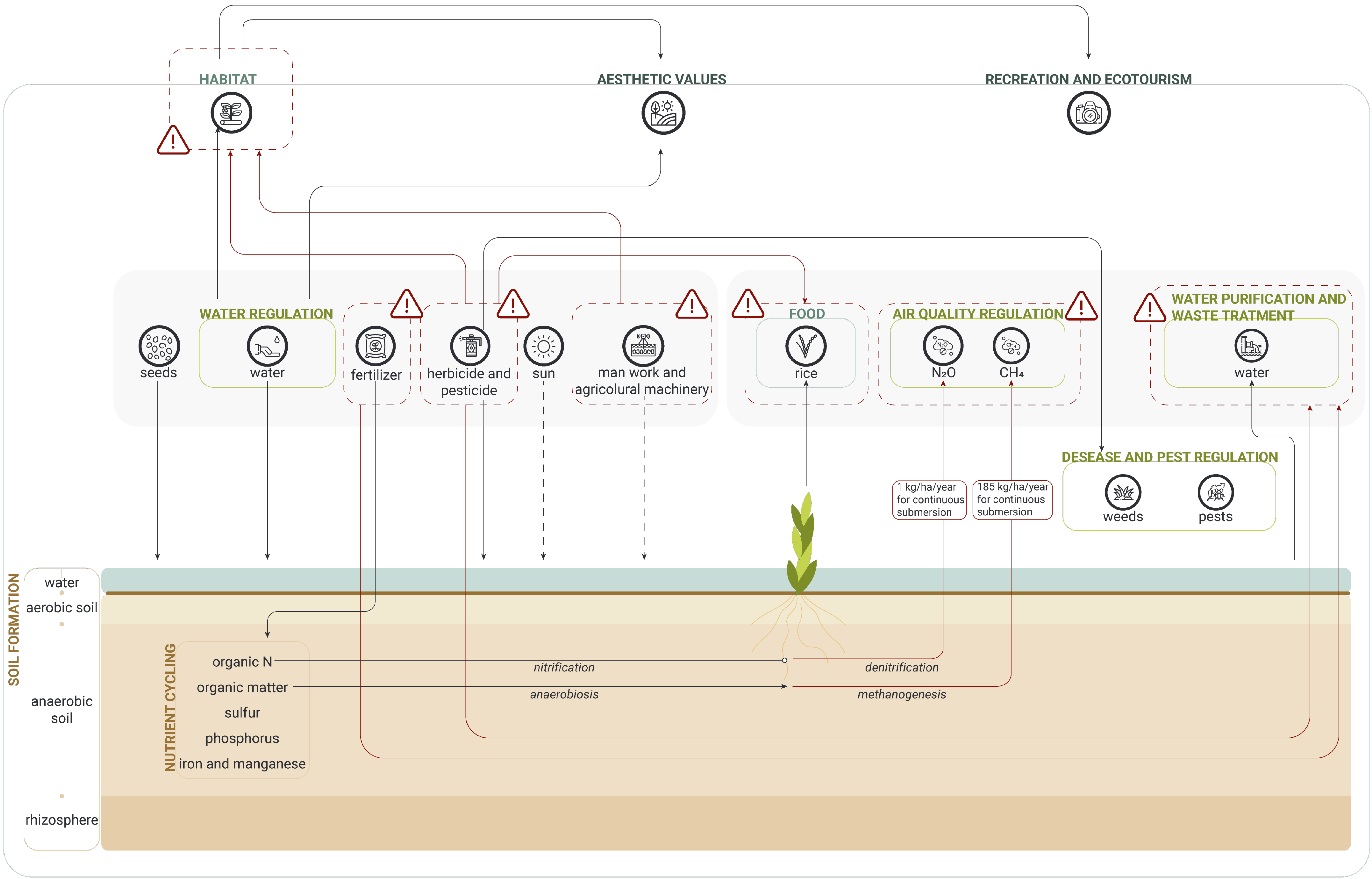


Fig.63 Graphical representation of the linear rice production process, with the red triangles are shown the dangers produced by conventional cultivation techniques

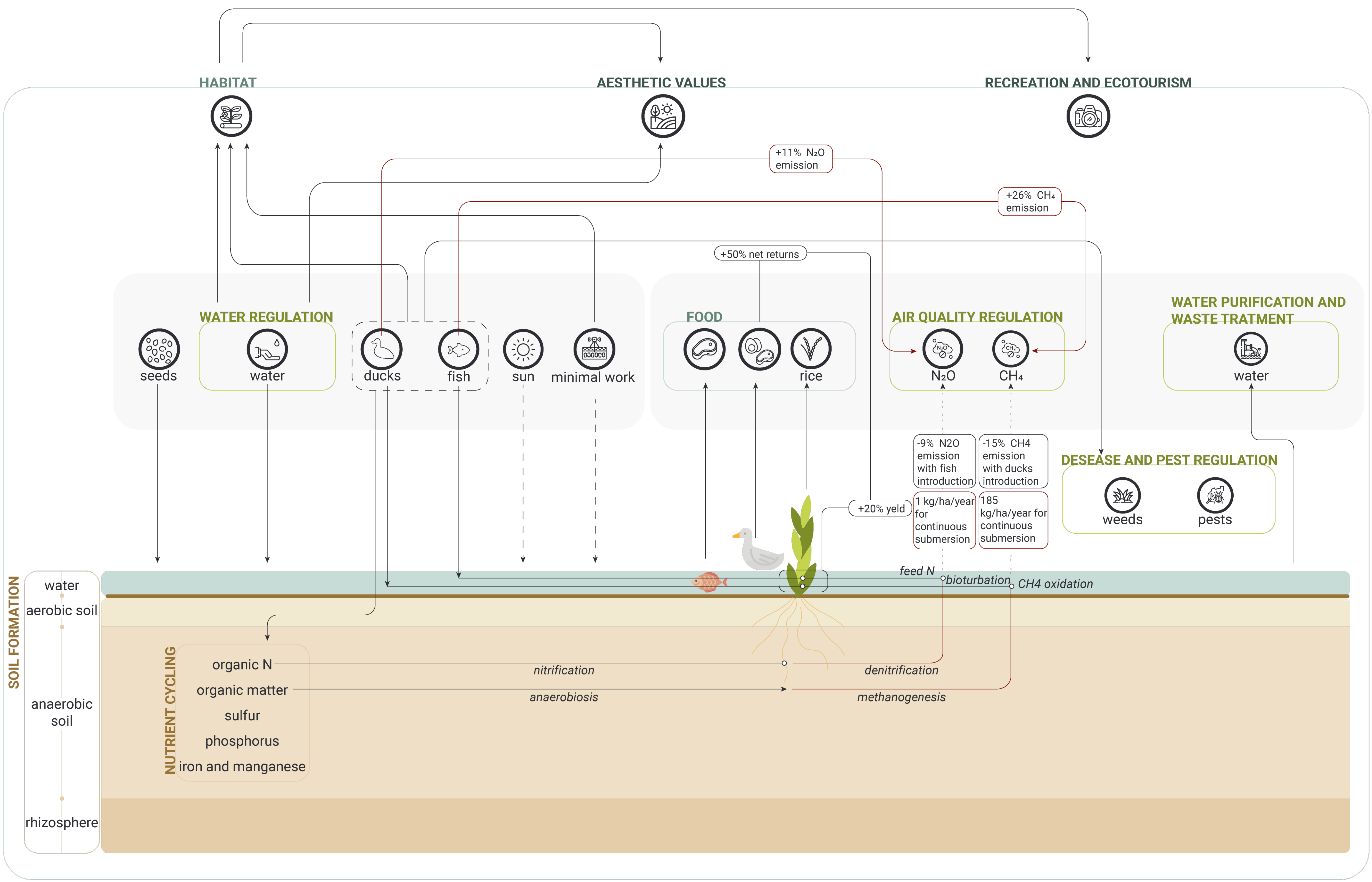


Fig.64 Graphical representation of the systemic rice production process

6.9 Systemic matrix

Fig.65 Analysis of the company new situation. In the x- and y-axes the evaluation parameters are positioned. With a percentage >12 the focus area is highlighted, with percentages ranging from 5 to 12 the attention area is represented and finally with percentages <5 the hinted presence area is pointed out

Overall, the company's situation has significantly changed as it is possible to see from Figure 63. As a matter of fact, the new system implementation has led to a change in percentages.
For example, the studies analysed from different parts of the world, especially from Asian countries, have increased the level of knowledge of agro-ecological techniques, such as the integration of agriculture and breeding, which are not practiced in Italy today.
The acquisition of this knowledge has produced a series of positive knock-on effects, for instance the exploitation of local resources such as the tench, which is part of the tradition of the Piedmontese cuisine, but also efficiency from various points of view in the production process, as well as returning to a technique used in Vercelli's rice fields in the past, thus combining tradition with modern innovative practices.
Above all, the new system has created a healthier environment, giving greater quality to the food products sold (rice, duck and fish meat and duck eggs) and respecting the environment in which this activity operates by restoring the ecosystem, thus spreading these values to the community.

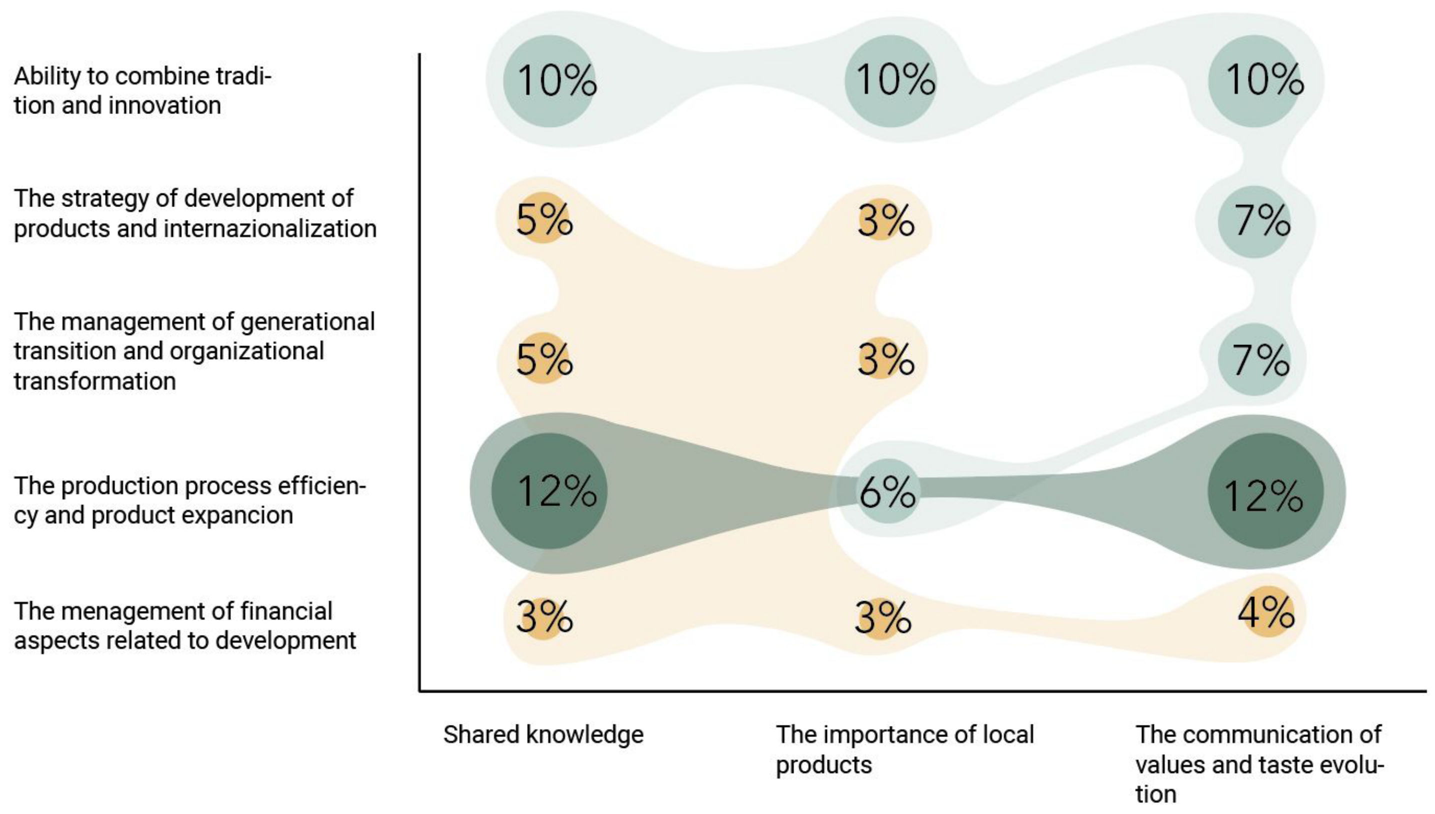



Photo by Hikarinoshita Hikari on Unsplash

7.0 Conclusions and final remarks

Overall the system is able to almost regulate itself because the outputs generated are also input for the cultivation process.
As shown in Figure 66, some of the outputs given by the system like nutrients, and weed and pest control are also used as input, replacing chemical products such as fertilizers and pesticides, also avoiding further processing in the production process.
Other outputs, such as the sale of food products, that were not produced by the company originally, generate new links with other activities in the area. Indeed, the new system creates a network of relationships at regional level where not only material but also knowledge is exchanged.
In fact, a number of local businesses were proposed to be supplied with the new food products.
The ducks can be sold to another farm in Vercelli (Monucco farm) which not only rears but also slaughters the ducks and other animals they have. The only breed of duck that this farm currently raises is the Muscovy duck (Cairina moschata), so the farm can add a new variety to the slaughtered products it sells.
As far as fish are concerned, the tench can be sold at the Amare fish shop in Vercelli, which respects the rules of sustainable fishing.
The farms selected for the purchase of inputs (ducks and fish) are also located in the Piedmont region. Fertilised Peking duck eggs can be purchased from the farm La Scarsa in Alessandria, while tench can be purchased from a farm in Cuneo (Cascina Gioannina).
As for the know-how for implementing this technique, it comes from studies from the international context, especially the Asian context where it is widespread.
It is important to remember, however, that this technique was also used in the Piedmontese rice fields in the last century, so it is possible to exploit some knowledge from the past.

The project was also presented to the owner of Priorato farm which was taken as a case study for project development, with the aim of obtaining feedback.
From the discussion after the presentation, it emerged that he was aware that tench were introduced in rice paddies in the past in order to raise the production, and that they disappeared with the advent of new intensive techniques.
He was also aware of some benefits such as the role of the fish in keeping the ditches clean thus avoiding

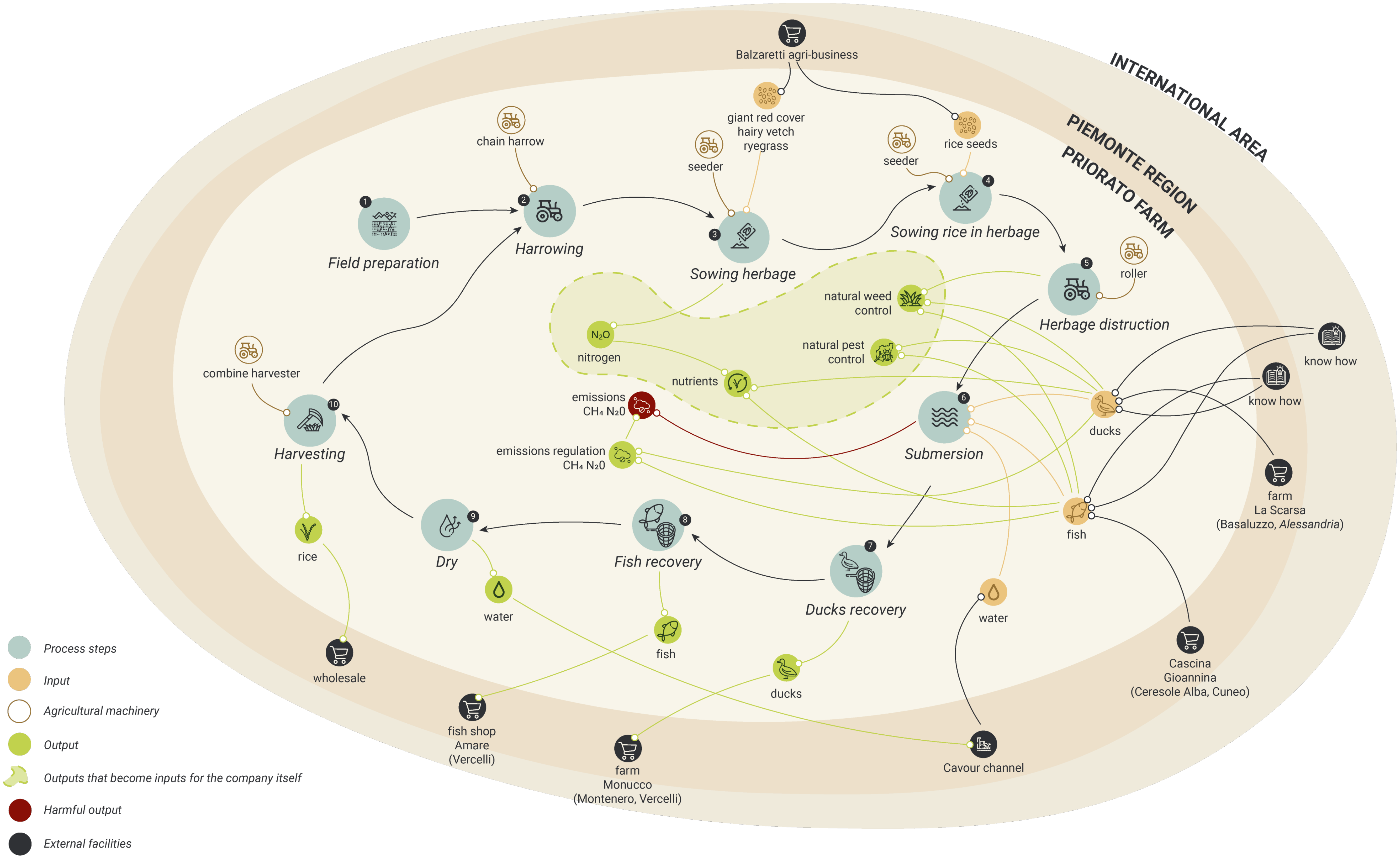


Fig.66 In the figure is represented the systemic vision of the company with the input and output analysis. In light blue are represented the process steps, in brown the agricultural machinery used for each step and in light brown the input of the process. The outputs are in green and those which become inputs for the system are surrounded by a light green spot. In red are represented the harmful outputs.

maintenance, and he was informed of the benefits that this system can have on humans, as fish feed on mosquito larvae (as do ducks), reducing their proliferation and creating a more liveable environment. One critical point he emphasised was the presence of numerous herons that could feed on the fish. However, there could be solutions to this problem, such as the installation of some ropes or nets on which holographic reflective tape is placed to keep them away. The owner of the farm was not informed of the many economic and ecological advantages, which he found very interesting, and stated that he is interested in applying the studied technique to his rice field, especially to diversify production in order to have other products to sell in case there is a loss in rice production in a crop.

The project, indeed, has demonstrated that integrated agriculture of rice, fish and ducks could bring many benefits from an ecological point of view.
In fact, these animals, if introduced to paddy fields, can provide various ecosystem services.
The movement of the ducks and fish in the paddy field chamber helps to dissolve atmospheric oxygen in the water, also regular loading of faecal matters and movement of the soil in search of food contribute to improved soil nutrients as well as increasing soil fertility.
In addition, ducks and fish are able to naturally regulate the presence of weeds and pests, because they feed on the species that infest rice fields.
These two ecosystem services provided by this integrated farming system make the use of chemicals such as fertilisers or pesticides unnecessary, creating positive knock-on effects.
For this reason, the chosen integrated farming system contributes to providing habitats for many species, thereby supporting the development of biodiversity.
An environment where the presence of man is minimal, a place where nature is the master, increases the aesthetic value of the place itself, thus creating destinations for ecotourism and educational activities in the natural environment.
Another ecosystem service produced by ducks and fish is the regulation of emissions.
Ducks increase nitrogen production but decrease methane production.
By contrast, fish increase methane emissions but

decrease nitrogen emissions.
So integrated agriculture helps in the ecosystem restoration and it generates diversity improving the system resilience.

This thesis has also demonstrated the economical feasibility of the project implementation.
To prove it, all the costs and revenues have been added to a five years business plan, considering all the new costs and the new revenues from the pilot project, the company total income has increased by the 26%, while the revenue from the pilot project have raised by the 50%.
In fact, the return on a plot of land equivalent to the pilot project (about five hectares) cultivated with the organic farming technique is 22.709,5 €. By converting this land to integrated agriculture, the income rises to 34.000 €.
This economic figure was calculated on the basis of organic rice production, and is due to both the 29% increase in rice productivity and the sale of new food products.
In particular, this result was obtained by crossing company data with data from international case studies.
So it turns out that in one year the pilot project (500 fish and 354 ducks) can produce about 198 kg of duck meat, 35 kg of fish meat and 3.976 eggs.
Based on the market price of 10 €/kg, 20 €/kg and 0,50 € per piece for duck meat, fish meat and eggs respectively, this results in an annual profit of 2.000 € for ducks, 700 € for tenches and 2.000 € for eggs.
For rice, on the other hand, 29% was added to the production of organic rice, which is 65 q/ha and the gain is 4.585 €/ha. This gives a gain of 29.300 € on the rice grown in the pilot project.
It is important to note, however, that with different soil and water conditions the results can be very different.
In fact, the soil of the farm is very fertile if compared for example with the Baraggia area where it is possible to have half the production of the farm studied.
The Baraggia area, in fact, being located further north, has a water temperature up to 4 degrees lower and a less fertile soil.
Therefore, considering this possibility, the gain of the pilot project on rice by applying the new system in Piedmont can vary from 14.648 € to 29.300 €.
These new revenues were added to those obtained on the rest of the farm's rice production.

Once the new and fixed costs have been taken into account, the company's total earnings in the last year of the business plan are 107.103 € (EBITDA), while those in year 0, when the pilot project was not implemented, are 84.738 € (EBITDA).
The total income has increased because of the new food products and the raise in rice production but also because integrated agriculture led to a decrease in costs, which are lower by the 30% and 15% compared with conventional agriculture and biological agriculture respectively.

In order to put this project into practice and therefore start up a breeding activity in the paddy field, in addition to carrying out all the actions described in the previous chapter, which comply with the regulations in force in Italy and in the Piedmont region in particular, it is necessary to fill out forms on the Piedmont Region website to notify the ASL and SUAP the start of the production activity.

In conclusion, this thesis shows that integrated agriculture of rice, ducks and fish, can solve several problems.
First of all, ecosystem restoration is achieved as minimally invasive techniques that respect the surrounding environment are used, thus providing habitats for numerous animal species, supporting the development of biodiversity.
Furthermore, this solution allows the production of different food products in a single plot of land, thus making the best use of the available space and significantly increasing the productivity of an area without damaging it.
Finally, the aim of the thesis was to demonstrate that this technique, applied to a paddy field in the Piedmont region, can produce not only ecological benefits but also economic ones.
The results obtained show that by applying an integrated farming system, in which fish and ducks are placed in a rice field, the total income of the farm can increase substantially.
In this particular case, in which the technique was applied exclusively to an area of about five hectares, the total income of the farm increased by 26%.

References

Photo by Pierre Bamin on Unsplash

- Agraria.org. (s.d.). Anatra di Pechino Tedesca (Anas platyrhynchos). Tratto il giorno 05 26, 2021 da Agraria.org: https://www.agraria.org/anatre/pechino.htm
- Agronotizie - Notizie per l'agricoltura. (2017, 07 03). Riso bio, pacciamatura vegetale per controllare le malerbe. Tratto da [Video]. YouTube: https://www.youtube.com/watch?app=desktop&v=1t9VRcOXJqs&ab_channel=Agronotizie-Notizieperl%27agricoltura
- AIAB Lombardia. (2015, 11 4). La pacciamatura verde. Tratto da AIAB Lombardia: https://www.aiablombardia.it/inerbimento-2/
- Alewu, B., & Nosiri, C. (2011). Pesticides and Human Health.
- Altieri, M. (2018). Agroecology: The Science of Sustainable Agriculture.
- Amin, M. M., Rowshon, M. K., & Aimru, W. (2011). Paddy Water Management for Precision Farming of Rice. Current Issues of Water Management, 107–142.
- Arpa Piemonte. (2014). Coltivazione del riso. Tratto da Arpa Piemonte: http://www.arpa.piemonte.it/reporting/indicatore-della-settimana/archivio-indicatori/archivio-2014/coltivazione-del-riso-1
- Arpa Piemonte. (2017). Emissioni da agricoltura. Tratto da Arpa Piemonte: http://relazione.ambiente.piemonte.it/2017/it/aria/fattori/agricoltura
- ARPA Veneto. (2017, Febbraio 16). Metodologia EMEP-EEA. Tratto da ARPA Veneto: https://www.arpa.veneto.it/temi-ambientali/aria/emissioni-di-inquinanti/metodologia-EMEP-CORINAIR#:~:text=La%20metodologia%2C%20denominata%20EMEP%2DCORINAIR,Nomenclature%20for%20Air%20Pollution%2097).
- Assaë, K. (n.d.). The ducks revolution traditional wisdom for sustainable agriculture. Tratto da Ideas Online: http://www.ideassonline.org/public/pdf/DucksRevolution-ENG.pdf
- Associazione Parco Delle Risaie Onlus, Connecting Cultures, & Comune di Milano. (2010). Parco delle risaie. Un cuore agricolo per la città di Milano. Tratto da http://www.spaziaperti.fondazionecariplo.it/implement_file.php?path=spaziaperti_document&id=4745&name=Parco_delle_Risaie_sintesi_non_tecnica.pdf&hash=5949e59a46c102bc2c6cdef04b56bb44
- Behera, U. K., Panighrahi, P., & Sarangi, A. (2012). Multiple Water Use Protocols in Integrated Farming System for Enhancing Productivity. Water Resources Management, 2605-2623.
- Benzaghta, M. A., Elwalda, A., Mousa, M., Rahman, M., & Erkan, I. (2021). SWOT analysis applications: An integrative literature review. Journal of Global Business Insights, 55-73.
- Bhattacharyya, P., Sinhababu, D. P., Roy, K. S., Dash, P. K., Sahu, P. K., Dandapat, R., . . . Mohanty, S. (2013). Effect of fish species on methane and nitrous oxide emission in relation to soil C, N pools and enzymatic activities in rainfed shallow lowland rice-fish farming system. Agriculture, Ecosystems and Environment, 53-62.
- Bressani, C. (2019, 12 16). Le risaie tornano a crescere: i dati del Vercellese e del Nord Italia nell'ultimo anno. Tratto da Le risaie tornano a crescere: i dati del Vercellese e del Nord Italia nell'ultimo anno: https://www.lastampa.it/vercelli/2019/12/16/news/le-risaie-tornano-a-crescere-i-dati-del-vercellese-e-del-nord-italia-nell-ultimo-anno-1.38218257
- Calaciura, B., De Amicis, T., Gisotti, M., & Zaghi, D. (2012). Rete Natura 2000 e Agricoltura. Progetto fa.re.na.it.
- Calhoun, A. J., Mushet, D. M., Bell, K. P., Boix, D., Fitzsimons, J. A., & Isselin-Nondedeu, F. (2016). Temporary wetlands: challenges and solutions to conserving a "disappearing" ecosystem. Biological Conservation, 3-11.
- Camera di commercio Biella e Vercelli. (2019). Listino settimanale dei prezzi all'ingrosso sulla piazza di Vercelli. Tratto da Camera di commercio Biella e Vercelli: http://images.vc.camcom.it/f/pricelist/PrezziIngrosso/PrezziIngrosso_20190528_22-mat.costr..pdf

- Cepollini, S. (2014, 8 8). Anatra Pechino. Tratto da Federazione Italiana Associazioni Avicole: https://www.fiavinfo.eu/anatra-pechino/
- Chinase Academy of Science. (2010). Proposal for Globally Important Agricultural Heritage Systems (GIAHS) Programme: Traditional Dong's Rice-Fish-Duck Agroecosystem in Southeast Guizou, China.
- Coltura & Cultura. (s.d.). Il riso è vita. Tratto da Coltura e Cultura: https://www.colturaecultura.it/articolo/il-riso-e-vita#:~:text=Il%20riso%20rappresenta%20la%20pi%C3%B9,oltre%203%20miliardi%20di%20persone).&text=In%20America%20Latina%20e%20nei,%2C%2043%25%20di%20quella%20mondiale.
- Commissione Europea. (2020). REGOLAMENTO DI ESECUZIONE (UE) 2020/464 DELLA COMMISSIONE del 26 marzo 2020. Tratto da https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:32020R0464&from=EN
- Consiglio regionale del Piemonte. (2020). Regolamento regionale 29 ottobre 2007, n. 10/R. Tratto da https://www.regione.piemonte.it/web/sites/default/files/media/documenti/2020-01/zzz_reg_10r_2007_testo_coordinato_vigente_al_01012020.pdf
- Cornell University College of Veterinary Medicine. (s.d.). Hatching Duck Eggs. Tratto il giorno 05 26, 2021 da Cornell University College of Veterinary Medicine: https://www.vet.cornell.edu/animal-health-diagnostic-center/programs/duck-research-lab/hatching-duck-eggs
- Cornunghia. (s.d.). Tratto da Geosism: https://www.geosism.com/offerte/1797-humocorn-800--n8---0-02-zn---31-c---25-kg---concime-granulare-per-ortaggi--vite-e-olivo-detail
- Corteva Agriscience. (2016). Impatti economici dell'evoluzione della gestione delle infestanti del riso in Italia. Tratto da Corteva: https://www.corteva.com/content/dam/dpagco/corteva/eu/ai/rinskor/rinskor/nomisma%20reduced%20pdf.pdf
- CREA - Ricerca da vedere. (2020, 10 16). Riso biologico: Tecnica della semina su coltura di copertura – pacciamatura verde. Tratto da [Video]. YouTube: https://www.youtube.com/watch?app=desktop&v=tt50Ck94qDI&ab_channel=CREA-Ricercadavedere
- Crosio, R. (s.d.). Le antiche tecniche di coltivazione del riso. Tratto il giorno 01 8, 2021 da Le Vocazioni Ambientali Del Vercellese, Terra d'acque: http://www.roberto-crosio.net/1_vercellese/habitat_antiche_tecniche.htm
- Dabney, S. M., Delgado, J. A., & Reeves, D. W. (2001). Using winter cover crops to improve soil and water quality. Communications in Soil Science and Plant Analysis, 32(7–8), 1221–1250.
- De Pasquale, M. (2019, 03 6). IL RILANCIO DEL RISO ITALIANO. Tratto da Ristorazione Italiana Magazine: https://www.ristorazioneitalianamagazine.it/rilancio-riso-italiano/
- De Simone, A. (2013, 08 28). Terreni argillosi, struttura e caratteristiche. Tratto da Idee Green: https://www.ideegreen.it/terreni-argillosi-26040.html
- Donnamoderna. (2014, Settembre 9). Anatra farcita alla piemontese. Tratto da Donnamoderna: https://ricette.donnamoderna.com/anatra-farcita-alla-piemontese
- Ente Risi. (2012, 05 30). INSETTI E PATOGENI. Tratto da Ente Risi: https://www.enterisi.it/servizi/Menu/dinamica.aspx?idSezione=17297&idArea=18353&idCat=18366&ID=18368&TipoElemento=categoria
- Ente Risi. (2015). Fertilizzazione della coltura. Tratto da Ente Risi: http://www.enterisi.it/upload/enterisi/documentiallegati/01_aazoto-dr.Marcoromani_13660_438.pdf
- Ente Risi. (s.d.). Il riso è vita. Tratto da Ente Risi: https://www.enterisi.it/RisoVita/2a.html
- Ente Risi. (s.d.). Il riso è vita. Tratto da Ente Risi: http://www.enterisi.it/RisoVita/2e.html#:%7E:text=Per%20un%20gran%20numero%20di%20contadini%2C%20i%20pesci%20e%20gli,unica%20fonte%20di%20proteine%20animali.&text=La%20tutela%20dell'ecosistema%20risaia,garantisce%20la%20conservazione%20della%20biodiversit%
- Ente Risi. (s.d.). La risicoltura in Italia. Tratto da Ente Risi: http://enterisi.it/upload/enterisi/documentiallegati/La%20risicoltura%20e%20la%20filiera%20risicola%20in%20Italia%202014_13660_369.pdf
- Erpicatura: cos'è e perché viene fatta. (s.d.). Tratto il giorno 02 04, 2021 da Noi Siamo Agricoltura: https://www.noisiamoagricoltura.com/erpicatura/
- European Environment Agency. (2012, 12 13). Acqua e agricoltura, prospettive ed esigenze. Tratto da European Environment Agency: https://www.eea.europa.eu/it/articles/acqua-e-agricoltura-prospettive-ed-esigenze
- European Environment Agency. (2019, 09 30). Nature's nutrient cycle. Tratto da European Environment Agency: https://www.eea.europa.eu/signals/signals-2019-content-list/infographics/agriculture/view
- FAO. (2009, Settembre 23). 2050: Un terzo di bocche in più da sfamare. Tratto da FAO: http://www.fao.org/news/story/it/item/35687/icode/
- Fao. (2018). Rice Cultivation. Tratto da Faostat: http://www.fao.org/faostat/en/#data/GR
- Fao. (2019). Crops. Tratto da Faostat: http://www.fao.org/faostat/en/#data/QC
- Fao. (s.d.). The diverse rice ecosystems. Tratto il giorno 01 6, 2021 da Fao: http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/sustainable-rice-systems/rice-what/it/
- Fasani, M. (2019, 01 20). LA ROTAZIONE FA BENE ALLA TERRA E AL PORTAFOGLIO. Tratto da Riso Italiano: https://www.risoitaliano.eu/la-rotazione-fa-bene/
- Ferrero, A., Angelini, R., & Ponti, I. (2008). Il riso. ART Servizi Editoriali S.p.A. Tratto da https://www.colturaecultura.it/riso
- Ferrero, A., Milan, M., Fogliatto, S., De Palo, F., & Vidotto, F. (2016). Ruolo della gestione dell'acqua in risaia nella mitigazione del rischio di contaminazione delle acque superficiali da prodotti fitosanitari. Tratto da https://core.ac.uk/download/pdf/302019466.pdf
- Ferrucci, D., & Marcone, A. (2017). La certificazione del metodo biologico: avicoli. Tratto da Agraria.org: https://www.rivistadiagraria.org/articoli/anno-2017/la-certificazione-del-metodo-biologico-avicoli/
- Fukuda, K. (2017). The Advantage of Natural Farming as an Eco-Friendly Way of Living: Practice and Discourse on the "Learners' Fields" in Fukuoka, Japan. Culture, Agriculture, Food and Environment, 40(1), 15–23.
- Fukuoka, M. (1985). The Natural Way of Farming. Tratto da http://www.patricioleon.cl/permacultura/books/Fukuoka/Masanobu Fukuoka - The Natural Way of Farming.pdf
- Giuliano, D., Rossi, P., Luoni, F., Celada, C., & Bogliani, G. (2017). Biodiversity Action Plan per le aree risicole dell'Italia Nord-occidentale.
- GÜREL, E. (2017). SWOT ANALYSIS: A THEORETICAL REVIEW. Journal of International Social Research, 994-1006.
- Halwart, M., & Gupta, M. V. (2004). Culture of fish in rice fields. Rome: FAO and The WorldFish Center.
- Hong-xing, X., Ya-jun, Y., Yan-hui, L., Xu-song, Z., Jun-ce, T., Feng-xiang, L., . . . Zhong-xian, L. (2017). Sustainable Management of Rice Insect Pests by Non-Chemical-Insecticide Technologies in China. Rice Science, 24(2), 61–72.
- Hossain, S. T., Sugimoto, H., Ahmed, G. J., & Islam, M. R. (2005). Effect of Integrated Rice-Duck Farming on Rice Yield, Farm Productivity, and Rice-Provisioning Ability of Farmers. Asian Journal of Agriculture and Development, 79-86.
- Il 53 per cento del riso europeo è coltivato in Italia. (2018, 04 16). Tratto da Chicchi Delle

Meraviglie: https://www.chicchidellemeraviglie.it/5850-2/
- Il Verde Mondo. (2016, Ottobre 18). 10 cose da sapere per allevare l'anatra di Pechino (o anatra comune). Tratto da Il Verde Mondo: https://www.ilverdemondo.it/it/blog/10-cose-da-sapere-per-allevare-anatra-pechino-369#:~:text=La%20riproduzione,uova%20tra%20novembre%20e%20dicembre.
- IRRI. (s.d.). The importance of rice. Tratto da Knowledge Bank IRRI: http://www.knowledgebank.irri.org/ericeproduction/bodydefault.htm#Importance_of_Rice.htm
- IRRI. (s.d.). Water management. Tratto da Rice Knowledge Bank: http://www.knowledgebank.irri.org/step-by-step-production/growth/water-management
- Ismea Mercati. (2020). Riso - News mercati. Tratto da Ismea Mercati: http://www.ismeamercati.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/10213
- Istat. (2020). Coltivazioni. Tratto da Istat: http://dati.istat.it/Index.aspx?DataSetCode=DCSP_COLTIVAZIONI
- Koohafkan, P., Altieri, M., & Holt Gimenez, E. (2012). Green Agriculture: Foundations for biodiverse, resilient and productive agricultural systems. International Journal of Agricultural Sustainability, 61-75.
- Korn, L. (2003). Masanobu Fukuoka's Natural Farming and Permaculture. Tratto da Permaculture: http://www.permaculture.com/node/140
- L'ecosistema delle risaie. (2019, 05 15). Tratto da Indispensabile Magazine: https://www.indispensamagazine.com/territorio/lecosistema-delle-risaie/
- L'IMPORTANZA DI UNA CONCIMAZIONE RAZIONALE DELLA RISAIA. (2003, 11 25). Tratto da AgroNotizie: https://agronotizie.imagelinenetwork.com/fertilizzanti/2003/11/25/l-importanza-di-una-concimazione-razionale-della-risaia/654
- L'ingegneria della risaia. (s.d.). Tratto il giorno 02 1, 2021 da Strada Del Riso Vercellese: https://www.stradadelrisovercellese.it/sai-di-riso/lingegneria-della-risaia.html
- La coltivazione del riso. (2013). Tratto da Riso Italiano: https://www.risoitaliano.eu/la-coltivazione-del-riso/
- LA PACCIAMATURA CHE NON CONVINCE. (2020, 02 28). Tratto da RisoItaliano: https://www.risoitaliano.eu/la-pacciamatura-che-non-convince/
- Lanfair, J. K. (s.d.). Water purification | Description, Processes, & Importance. Tratto da Encyclopedia Britannica: https://www.britannica.com/topic/water-purification
- Lawler, S. P. (2001). RICE FIELDS AS TEMPORARY WETLANDS: A REVIEW. Israel Journal of Zoology, 513-528.
- Le tecniche di coltura del riso. (s.d.). Tratto il giorno 02 04, 2021 da Strada Del Riso Vercellese: https://www.stradadelrisovercellese.it/sai-di-riso/le-tecniche-di-coltura-del-riso.html#:~:text=La%20falsa%20semina%20%C3%A8%20semplicemente,e%20si%20eliminano%20gli%20infestanti.
- Le varietà di riso DOP. (s.d.). Tratto il giorno 02 1, 2021 da Riso Di Baraggia: https://www.risobaraggia.it/projects/1-i-risi-della-baraggia/
- Living Circular. (2015, Gennaio 7). Takao Furuno and his "duck rice". Tratto da Living Circular: https://www.livingcircular.veolia.com/en/inspirations/takao-furuno-and-his-duck-rice
- Lu, S. G., Sun, F. F., & Zong, Y. T. (2014). Effect of rice husk biochar and coal fly ash on some physical properties of expansive clayey soil (Vertisol). CATENA, 114, 37–44.
- Luo, Y., Fu, H., & Traore, S. (2014). Biodiversity Conservation in Rice Paddies in China: Toward Ecological Sustainability. Sustainability, 6(9), 6107–6124.
- Ministero della Transizione Ecologica. (2020). Prezzi medi mensili dei carburanti e combustibili. Tratto da Governo Italiano: https://dgsaie.mise.gov.it/prezzi_carburanti_mensili.php
- Ministry for the Environment. (s.d.). Why good air quality is important. Tratto da Ministry for the Environment: https://www.mfe.govt.nz/more/environmental-reporting/air/air-domain-report-2014/why-good-air-quality-important
- Mollica, M. (2019, 10 29). Tra Vercelli e Novara, nelle terre del riso. Tratto da Viaggi Corriere: https://viaggi.corriere.it/weekend/tra-vercelli-novara-terre-riso-4d4ecaa8-e507-11e4-845e-5bcd794907be/
- Nayak, P. K., Nayak, A. K., Panda, B. B., Lal, B., Gautam, P., Poonam, A., . . . Jambhulkar, N. N. (2018). Ecological mechanism and diversity in rice based integrated farming system. Ecological Indicators, 91, 359–375.
- Nayaka, P. K., Nayaka, A. K., Pandaa, B., Lalb, B., Gautamc, P., Poonama, A., . . . Jambhulkara, N. N. (2018). Ecological mechanism and diversity in rice based integrated farming system. Ecological Indicator, 359-375.
- Norton, L. R., & Heong, K. L. (2010). Rice Pest Management: Issues, projections, and Implications. Rice in the 21st Century Global Economy: Strategic Research and Policy Issues for Food Security, 297–332. Tratto da https://www.researchgate.net/publication/243055534_Rice_Pest_Management_Issues_projections_and_Implications
- Nuemsi, P. K., Tonfack, L. B., Taboula, J. M., Mir, B. A., Mbanga, M. B., Ntsefong, G. N., . . . Youmbi, E. (2018). Cultivation systems using vegetation cover Improves Sustainable Production and Nutritional Quality of New Rice for Africa in the Tropics. Rice Science, 25(5), 286–292.
- Original Italy. (s.d.). Anatra ripiena alla novarese. Tratto da Original Italy: http://www.originalitaly.it/it/ricette/r-anatra-ripiena-alla-novarese
- Passini, S. (2014, 11 13). Il mondo del riso. I trend nel consumo globale. Tratto da Expo 2015: http://www.expo2015.org/magazine/it/economia/il-mondo-del-riso.html
- Pescare.biz. (2018, Novembre 10). Il pesce Tinca: caratteristiche, morfologia, habitat, riproduzione. Tratto da Pescare.biz: https://www.pescare.biz/214/il-pesce-tinca-caratteristiche-morfologia-habitat-riproduzione/
- Peyron, M., Bertola, C., Pelissetti, S., Said-Pullicino, D., Celi, L., Miniotti, E., . . . Sacco, D. (2016). Greenhouse gas emissions as affected by different water management practices in temperate rice paddies. Agriculture, Ecosystems and Environment, 17-28.
- Piemonteagri. (n.d.). TINCA GOBBA DORATA DEL PIANALTO DI POIRINO. Tratto da Piemonteagri: http://www.piemonteagri.it/qualita/it/prodotti/pesci/379-tinca-gobba-dorata-del-pianalto-di-poirino
- Più CO2 in atmosfera, il riso sta diventando meno nutriente. (2018, 05 26). Tratto da Sky TG24: https://tg24.sky.it/ambiente/2018/05/25/co2-diminuisce-capacita-nutritiva-riso#:%7E:text=L'aumento%20dell'anidride%20carbonica,e%20vitamine%20di%20questo%20cereale
- Plato, L., & Meskin, A. (2014). Aesthetic Value. Encyclopedia of Quality of Life and Well-Being Research, 76–78.
- Polyculturae. (2019, 07 20). Marchio Biodiversitas – ASSOCIAZIONE DI PRODUTTORI AGRICOLI "POLYCULTURAE.". Tratto da Polyculturae: http://www.polyculturae.it/category/marchio-biodiversitas/
- Porcellotti, S. (n.d.). Tinca, Tinca tinca (Linnaeus, 1758). Tratto da Ittiofauna: http://www.ittiofauna.org/webmuseum/pesciossei/cypriniformes/cyprinidae/tinca/tincatinca/t_tinca.htm

- Provincia di Vercelli. (2019, 12 31). Tratto da Tuttitalia: https://www.tuttitalia.it/piemonte/provincia-di-vercelli/
- Qualigeo. (n.d.). Tinca Gobba Dorata del Pianalto di Poirino DOP. Tratto da Qualigeo: https://www.qualigeo.eu/prodotto-qualigeo/tinca-gobba-dorata-del-pianalto-di-poirino-dop/
- Queensland Government. (2013, 10 8). How soils form. Tratto da Environment, Land and Water | Queensland Government: https://www.qld.gov.au/environment/land/management/soil/soil-explained/forms
- Regione Lombardia. (2020). Bioblitz Lombardia da casa mia. Tratto da Regione Lombardia: https://www.regione.lombardia.it/wps/portal/istituzionale/HP/istituzione/Agenda/DettaglioEvento/servizi/enti-e-operatori/ambiente-ed-energia/parchi-e-aree-protette/bioblitz-16-17-maggio-2020-in-forma-virtuale/bioblitz-16-17-maggio-2020-in-forma-virtuale#:~
- Regione Piemonte. (2016). Deliberazione della Giunta Regionale 3 agosto 2018, n. 104-7430. Tratto da Regione Piemonte: http://www.regione.piemonte.it/governo/bollettino/abbonati/2018/34/attach/dgr_07430_990_03082018.pdf
- Regione Piemonte. (2020). Programma di sviluppo rurale. Tratto da https://www.regione.piemonte.it/web/temi/agricoltura/programma-sviluppo-rurale-2014-2020
- Regione Piemonte. (2021). Elenco prezzi agricoltura 2021 Allegato B. Tratto da https://www.regione.piemonte.it/web/sites/default/files/media/documenti/2021-03/dd-a17-146-2021-all_2-elenco_prezzi_2021.pdf
- Regione Piemonte. (n.d.). Risaie Vercellesi. Tratto il giorno 2021 da Regione Piemonte: http://www.regione.piemonte.it/habiweb/servlet/image.pdf?idSic=102
- Rice Knowledge Bank. (s.d.). Rice-fish systems. Tratto da Rice Knowledge Bank: http://www.knowledgebank.irri.org/training/fact-sheets/crop-establishment/item/rice-fish-systems-fact-sheet
- Riso – Guida completa: origine, storia, varietà, coltivazione, lavorazione, cucina. (2019, 10 7). Tratto da Gustorotondo: https://www.gustorotondo.it/riso/
- Riso Vignola. (s.d.). Un progetto unico al mondo. Tratto il giorno 02 04, 2021 da Riso Vignola: http://www.risovignola.it/it/pacciamatura/
- Ristec. (s.d.). Sovescio. Tratto il giorno 02 04, 2021 da Ristec: https://www.stradadelrisovercellese.it/sai-di-riso/le-tecniche-di-coltura-del-riso.html#:~:text=La%20falsa%20semina%20%C3%A8%20semplicemente,e%20si%20eliminano%20gli%20infestanti.
- Rosegrant, M. W., Ringler, C., & Zhu, T. (2009). Water for Agriculture: Maintaining Food Security under Growing Scarcity. Annual Review of Environment and Resources, 34(1), 205–222.
- Runner, D. (2021, Febbraio 9). Everything You Need to Know About Pekin Ducks. Tratto da Pethelpful: https://pethelpful.com/farm-pets/pekin-ducks
- Senato della Repubblica. (2021). Legislatura 14ª - Disegno di legge N. 2483. Tratto da http://www.senato.it/japp/bgt/showdoc/frame.jsp?tipodoc=Ddlpres&leg=14&id=00089634&part=doc_dc&parse=no
- Sheng, F., Cao, C.-g., & Li, C.-f. (2018). Integrated rice-duck farming decreases global warming potential and increases net ecosystem economic budget in central China. Environmental Science and Pollution Research, 22744–22753.
- Shiming, L., & Gliessman, S. R. (2016). Agroecology in China: Science, Practice, and Sustainable Management.
- SI FA PRESTO A DIRE RISPARMIO IDRICO... (2015, 03 13). Tratto da RisoItaliano | Il Portale Del Riso: https://www.risoitaliano.eu/si-fa-presto-a-dire-risparmio-idrico/

- Sistema Piemonte. (2020). Anagrafe agricola unica. Tratto da Sistema Piemonte: http://www.sistemapiemonte.it/fedwanau/elenco.jsp
- Statista. (2019). Principal rice exporting countries worldwide in 2018/2019. Tratto da Statista: https://www.statista.com/statistics/255947/top-rice-exporting-countries-worldwide-2011/
- Statista. (2020). Rice consumption worldwide in 2019/2020, by country (in 1,000 metric tons). Tratto da Statista: https://www.statista.com/statistics/255971/top-countries-based-on-rice-consumption-2012-2013/
- Strada Del Riso Vercellese. (s.d.). La risaia vercellese: oasi naturale d'Europa. Tratto da Strada Del Riso Vercellese: https://www.stradadelrisovercellese.it/sai-di-riso/la-risaia-vercellese-oasi-naturale-deuropa.html
- Strada Del Riso Vercellese. (s.d.). La storia del riso nel Vercellese. Tratto da Strada Del Riso Vercellese: https://www.stradadelrisovercellese.it/sai-di-riso/la-storia-del-riso-nel-vercellese.html
- Strada, A. G. (1928). Il trapianto del riso.
- Teng, Q., Hu, X.-F., Cheng, C., Luo, Z., Luo, F., Xue, Y., . . . Yang, M. (2016). Ecological effects of rice-duck integrated farming on soil fertility and weed and pest control. J Soils Sediments, 2395–2407.
- The Happy Chicken Coop. (2020, 11 3). Pekin Duck Breed: Everything You Need To Know. Tratto da The Happy Chicken Coop: https://www.thehappychickencoop.com/pekin-duck-breed-everything-you-need-to-know/
- The International Ecotourism Society. (s.d.). What Is Ecotourism. Tratto da The International Ecotourism Society: https://ecotourism.org/what-is-ecotourism/
- Una Garlanda. (s.d.). La Nostra Storia – Una Garlanda. Tratto il giorno 03 12, 2021 da Una Garlanda: https://www.unagarlanda.it/la-nostra-storia/
- Vercelli. (s.d.). Tratto il giorno 01 31, 2021 da Italia: http://www.italia.it/it/scopri-litalia/piemonte/vercelli.html
- Verhoeven, J. T., & Setter, T. L. (2010). Agricultural use of wetlands: opportunities and limitations. Annals of Botany, 155-163.
- Vlados, C. (2019). On a correlative and evolutionary SWOT analysis. Journal of Strategy and Management, 347-363.
- Wan, N.-F., Li, S.-X., Li, T. C., Weiner, J., Zheng, X., Ji, X., . . . Li, B. (2019). Ecological intensification of rice production through rice-fish co-culture. Journal of Cleaner Production, 1002-1012.
- Wikipedia. (2021, 01 19). SWOT analysis. Tratto da Wikipedia: https://en.wikipedia.org/wiki/SWOT_analysis
- Xu, G., Liu, X., Wang, Q., Yu, X., & Hang, Y. (2017). Integrated rice-duck farming mitigates the global warming potential in rice season. Science of the total environment, 58-66.
- YUAN, W., CAO, C., LI, C., ZHAN, M., CAI, M., & WANG, J. (2009). Methane and Nitrous Oxide Emissions from Rice-Duck and Rice-Fish Complex Ecosystems and the Evaluation of Their Economic Significance. Agricultural Sciences in China, 8(10), 1246–1255.
- Zheng, H., Huang, H., Chen, C., Fu, Z., Xu, H., Tan, S., . . . Tang, J. (2017). Traditional symbiotic farming technology in China promotes the sustainability of a flooded rice production system. Sustain Sci, 155–161.

Acknowledgments

At the end of this paper I would like to thank all the people who contributed to the writing of my thesis.
My special thanks go to my thesis supervisor Elena Comino and PhD Candidate Laura Dominici who have assisted and guided me, step by step, along this project, thanks to which I have acquired knowledge and a working method that will certainly be useful to me in my future paths, whatever they may be.
I would also like to thank Mattia Pastore, owner of the Priorato company, for providing me with the data concerning his company and for his kind and helpful cooperation.
Finally, I would like to thank my whole family for their support, especially my parents and my sister.
Last but not least, I would like to thank my friends, especially those with whom I have shared this journey (Elisabetta, Nicole e Ilaria), Laura Pagliardini who, even though she is far away, has supported me every day and Valentina, our walks gave me all the psychological help I needed.