Review on Impact of Agro-Silvo-Pastoral Management and Climate Changes on Mountain Semi-Natural Grasslands in the North-Western Italian Alps

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ABSTRACT
In biodiversity conservation, water management and maintaining cultural heritage, the mountain semi-natural grasslands in the north-western Italian Alps are playing an important role. Historically, traditional agro-silvo-pastoral systems integrating agriculture, forestry and grazing practices were cultured here to sustainably manage landscapes. However, the shift towards modern monoculture farming has led to biodiversity loss, soil erosion and reduction of ecosystem resilience amidst climate change impact. The aim of the study is to critique the impact of agro-silvo-pastoral management and climate change on these mountain semi-natural grasslands. The main focus is to compare the traditional polyculture systems with contemporary monoculture methods to examine their ecological, economic and social implications, by providing a multidisciplinary approach encompassing ecological assessments, biodiversity indices and ecosystem service valuation. The environmental impacts and benefits will be evaluated by statistical analysis and ecological economics principles. By redesigning resilient agroforestry models aligning ecological principles the study will further explore to contribute into biodiversity conservation, ecosystem service enhancement and sustainable agroforestry based agroecosystem exploration in mountain regions of North -western Italy. The research results will strive to enlighten policy interventions for promoting agroecological resilience and sustainable land management in the Italian Alps and other similar mountain ranges of Europe under changing climatic conditions.

Keywords: Agro-silvo-pastoral systems, climate change, semi-natural grasslands, biodiversity conservation, sustainable agriculture, Susa Valley, Italian Alps, ecosystem services, ecological economics, UN SDGs

1. Introduction

Mountain areas for instance the Susa Valley of Turin in Italy are not just geographical features but biodiverse systems associated with numerous ecological processes and are culturally relevant. These regions are involved in water control and removal of impurities affecting the immediate populations and the later stages downstream. Still, the changes in the uses of lands of Southern Europe's cultural mountains, such as in Italy in the 20th century, were characterized by depopulation and the abandonment of the traditional agro-silvo-pastoral system (Fiore, Piras Santoro 2024). This transition has been made at the expense of grasslands and traditional agriculture hence positively affecting forest cover (Bruno et al., 2021). The disintegration of the community's agro-silvo-pastoral practices not only have an impact on the biodiversity of the place but also intensifies knowledge about the interactions between agrosilvo-pastoral practices, climate change and semi-natural, mountain grasslands could be important in the management of these ecosystems. This research mainly aims to evaluate the effects of agro-silvo-pastoral dynamics and climate changes on semi-natural grasslands within the North-Western Italian Alps, more precisely in the Susa Valley. Intercropping and mixed crop and livestock farming, allocate various crops and animals in a way that suggests nature's complexity and have authored agriculture for centuries and can show ways to feed the world sustainably in the face of the pressing problems of habitat destruction, species loss, and climate change. This research aims to prove that diversified agriculture increases ecosystem sustainability through the metrics of natural capital, appraisal of biological diversity, and analysis of the ecosystem services delivered by ancient agriculture practices. It is believed that the conclusions will be useful for policymakers and practitioners to enhance the decision-making process of modern agriculture practices to encourage economic recovery and environmental conservation within mountainous areas. Therefore, this research is relevant in addressing the existing environmental challenges while enhancing sustainable development to tackle the planetary crisis of climate change, loss of biotic productivity, and pollution. Through the analysis of the advantages of polyculture and sustainable agroecosystems, thus promoting the change of mentality to the use of long-lasting resources for the following generations.

2. Literature Review

North-Italian Alpine region with a focus on the Susa Valley is a diverse, and connected living environment that was characterized by historical agro-silvo-pastoral multifunctional landscapes which were active up to the mid 20th Century (Piras et al., 2024). These systems of water management and agricultural production developed in parallel to moderate the impacts of fast water flow from the mountains. It is necessary to conduct research on the relationship between agro-silvo-pastoral systems, climate change and semi-natural mountain grasslands. The adoption of modern farming methods in hilly areas has led to decreased biodiversity and ecosystem services which are vital for sustainable progress in long term (Aguilera et al., 2021). The effects of climate change increase these problems. It changes land management strategies. It also lowers production in grasslands (Dibari et al., 2021). Silvopastoralsystems, are a vital part of Europe's natural and cultural heritage. It combines cow grazing with wooded areas, particularly the larch tree forests of the Western Alps. According to current research, there is a move away from commercialization-oriented systems and toward classic agro-silvo-pastoral approaches. The effects are seen when it influences the local plant communities such as the Sardinian meriagos (Scoones, 2021). The changes are caused by innate laws concerning the physical use and control of the land. These are instrumental in excluding people and maintaining the integrity of environmental systems (Varela et al., 2022). Sylviculture mixes the grasses with trees in a particular systems. It is effectively used in the exploitation of natural resources all the farmed environments. They improve the quality of life of animals and are friendly on the environment (Barrios et al., 2020). A lot more researches are demanded mostly to assess the net effects of these systems on all the aspects of species diversity conservation, wildlife protection, and lessening the effects of the climate change. Effective management of silvo-pastoral environments involves solving stakeholder concerns (Rolo et al., 2020). Use innovative methods and collaborative leadership to solve issues while integrating traditional methods. key research questions include: i) In what way is the implementation of ASP systems connected with influencing the modern monoculture agricultural practices and the biodiversity and ecosystem services? ii) Susa Valley is the source of long-term impacts of climate change on semi-natural grasslands. iii) Plans on how farming, a traditional method of producing foods can be integrated with Agri-food technologies for better efficiency in mountainous areas? iv) Changing from traditional agro-silvo-pastoral systems to modern agriculture; What are the social and economic issues facing the North-Western Italian Alps region?

3. Problem Statement and Focused Solution

3.1 Research Problem

Agriculture is a process of domestication, breeding, and culture of living organisms, such as plants, animals, and microorganisms, in open fields or in closed environments, for the production of food and other useful materials for man. Agriculture is a business of the farmer and a management science (farm management) that aims to minimize the risk and cost of production of crops and to maximize the profit of the farmer. There are many agricultural systems in the world which can broadly be classified into two main types, monoculture and polyculture. Conventional agriculture (monoculture or anti- biodiversity agriculture) is the predominant system of agriculture, all over the world. Monoculture intends to raise one single species of plant or animal in a farm and intends to eliminate all other plants, animals, and microorganisms (biodiversity) from that farm, by applying toxic chemicals (herbicides, pesticides, fungicides, and antibiotics). Monoculture is responsible for many burning problems of the world, such as deforestation, habitat loss, species extinction, soil erosion, soil degradation, desertification of land, depletion of groundwater, contamination of groundwater with pesticides and heavy metals, eutrophication, emission of greenhouse gases, climate change, biodiversity loss, pollution, genetic erosion, the incidence of insect pests, diseases and weeds in crops, herbicide resistance in weeds, pesticide resistance in pests, antibiotic resistance in bacteria, pesticide residues in food, microplastic contamination in food, the low nutritive value of food, obesity, cancer and food waste.

3.2 Focused Solution

Polyculture or traditional biodiversity-based agricultural systems manage the natural capital of the farm and biodiversity of living organisms such as plants, animals, and microorganisms, to create agroecosystems, which closely mimic natural ecosystems, to automate and optimize crop production and crop protection. A well-designed polyculture system can minimize the risk and cost of production of crops while maximizing the aggregate yield and profit of the farmer. Indigenous people invented the process of agriculture about 10,000 years ago, during the Holocene and some of these traditional agricultural landscapes persist in different mountain regions of the world. The traditional agricultural knowledge of the indigenous people can be a good source of knowledge for the development of modern sustainable agriculture systems. Various polyculture systems of the world can be classified into two types, traditional agricultural landscapes and the new brands of agriculture developed by individuals using traditional agricultural knowledge. When polyculture systems include forest trees, it is known as agroforestry.

4. Research Objectives

4.1. Agroecosystem Analysis of Traditional Agricultural Landscapes in Italy

4.2. Development of a Theoretical Model of Sustainable Agroforestry System for Europe 4.3. Development of Nature Based Solution (NbS) to achieve the Sustainable Development Goals of the UN, the Biodiversity Goals of the EU, and the mitigation of the triple planetary crisis (climate change, biodiversity loss, and pollution) of the world.

5. Research Methodology

5.1. Agroecosystem Analysis of Traditional Agricultural Landscape

5.1.1. Inventory of Natural Capital

- Non-living components of the agroecosystem such as soil minerals (sand, silt and clay), chemical elements, organic matter, water and air and their physical, chemical and biological properties.
- Living components of the agroecosystem such as plants, animals and microorganisms.
- Environmental factors such as atmospheric temperature, soil temperature, water temperature, rainfall, snowfall, relative humidity, sunshine hours, wind velocity and wind direction.
- Human capital such as traditional agricultural knowledge. TAK is oral, therefore documentation and characterisation of TAK is important.
- Management of Natural Capital

5.1.2. Measurement of soil health and plant health

5.1.2. Valuation of Natural Capital

- Shadow Pricing:
- Life Cycle Analysis (LCA)
- Atkins approach

5.1.3. Inventory of agrobiodiversity

- Plants
- Animals
- Microorganisms

5.1.4. Measurement of Agrobiodiversity

- Species Abundance at genetic level, species level and ecosystem level.
- Species Richness
- Biodiversity Index
- Trophic levels, food web, food pyramid
- Interspecific interactions
- Area Effect on Biodiversity
- Edge Effect on Biodiversity

5.1.5. Interspecific Interactions

- Plant-plant interactions: weed,
- Plant-animal interactions: earthworms, pollinators, pests,
- Plant-microorganisms interactions: symbiosis, AMF, PGPR, pathogens, probiotics
- Animal-animal interactions: predators, parasites, competitors, beneficial animals, poisonous animals
- Animal-microorganisms interactions: pathogens,
- Microorganism-microorganism interactions: antagonism, parasitism,

5.1.5. Management of Agrobiodiversity

- Plant Biodiversity Management: (1) Rating and ranking of plant species, on the basis of their ecosystem services, (2) Plant domestication, (3) Plant Breeding, (4) Plant portfolio design and management, (5) Agroecosystem design and management and (6) Secondary plant succession management.
- Animal Biodiversity Management: (1) Animal domestication, (2) Animal breeding, (3) Animal portfolio (farm animals, feral animals and aquatic animals) design and management. (4) Pest animal management.
- Microorganism Biodiversity Management: (1) Microorganism domestication, (2) Probiotics, (3) Pathogenic microorganisms management.

5.1.6. Inventory of Ecosystem Services

- Provisioning Ecosystem Services such as crop yield and timber yield.
- Regulating Ecosystem Services such as water cycle, carbon cycle, nitrogen cycle, phosphorus cycle, potassium cycle, pollination and natural control.
- Cultural Ecosystem Services such as recreation, spiritual and religious activities.
- Management of Ecosystem Services through civil engineering and management of agrobiodiversity

5.1.7. Valuation of Ecosystem Services

- Provisioning Ecosystem Services: Market price.
- Regulating Ecosystem Services: Replacement cost, comparison of alternative scenarios,
- Cultural Ecosystem Services:

5.1.8. Ecological Economics
- Ecological Cost of Production
- Measurement of soil health, plant health, animal health, human health and environment health (one health)
- Management of ecological economics.

5.1.9. Statistical Analysis and Mathematical Modeling
- Holistic statistical analysis of complex datasets

5.2. Development of a theoretical model of sustainable agroforestry system

- Development of mathematical models for the functions of the agroecosystems such as water conservation, plant nutrition, pollination and natural control.
- Foundation of computational agriculture or theoretical agriculture

6. Expected Outcomes

The research objective is to investigate the effect of agro-silvo-pastoral systems and climate change on mountain semi-natural grasslands in northwestern Italian Alps. It will do this through investigating conventional monoculture practices in search of traditional agriculture landscapes in the Susa Valley, Turin, Italy. Conversely, it seeks to emphasize the sustainability and resilience of diverse farming systems by illustrating how such farming is ecologically friendly. The study also deals with current issues concerning global warming, loss of biodiversity and environmental pollution. It is expected that it will give irrefutable evidence in support for using traditional agroecology practices as a means for mitigating various negative impacts caused by humans on environment.

7. Significance of the study

i)Sustainable Agricultural Transition: It is a reminder of the immediacy to move from monoculture to agro-silvo-pastoral systems that are sustainable. Focusing on polycultures in Susa Valley, this study seeks to show how diversified agroecosystems can be used as buffers against habitat degradation, soil erosion and biodiversity extinction leading to long-term food independence and sustainable use of natural resources. ii) **Conservation of Biodiversity and Ecosystem Services :**This paper assesses natural capital, biodiversity and ecosystem services in traditional agroecosystems. It also calculates species richness and showshow polycultures can enhance ecosystem resilience necessary for sustainable agriculture production as well as environmental health. iii) **Development of Sustainable Agricultural Models:** Thus, it offers the theoretical basis for the long-term productive use of shrubs and trees by local people in European environments as well as an integration of its knowledge with current concepts of ecology. The UN Sustainable Development Goals (SDGs) or EU Biodiversity Goals are supported by this organization. iv) **Policy and Practice Implications:** These discoveries shape policy resolution and interventions for organic food systems, stability in mountains. The recommendations have to do with the economic and ecological advantages of polyculture, comprised of the global attempts to control food production and the preservation of natural resources.

8. Scopes and Limitations:

9.1 Research Scopes:

i)Geographical Concentration: The Susa Valley adjacent to Turin, Italy, distinguished for its age-old agro-silvo-pastoral methodologies. ii) **Ecological Focus:** Consideration of biodiversity indices, ecosystem provisions (provisioning, regulating, cultural) and appraisal of natural capital. iii) **Economic and Environmental View:** Looking at how traditional and modern farming methods affect the economy and the environment. iv) **Rules and Actions Impact:** Creating plans for taking care of land and protecting different types of plants and animals. v) **Numbers and Statistical Study:** Using complex number checks and statistical tools to understand how well ecosystems can handle changes and adapt to climate change.

9.2 Limitations:

i) Lack of adequate information regarding old farming methods. ii) Absence of historical records hinders the understanding of how farming has impacted the environment over an extended period. v) Different environmental conditions of different parts of SussaValley, might affect the application of findings from one area to another. vi) It is difficult to come up with a single idea for sustainable farming with trees by consensus of everyone who has diverse perspective about farming. vii) Due to technology limitations use of advance statistics to analyze complex environmental data can be difficult.

11. Potential Benefits

This study will demonstrate that the role of agro-silvo-pastoral systems for mitigating triple planetary crisis (climate change, biodiversity and pollution) is still strained in NW Italian Alps particularly in Susa Valley. The measurements such as biodiversity indices; ecosystem services valuation especially cultural services like landscape aesthetics should be integrated with assessing the performance of sustainable agroforestry models aligned with UN SDGs, EU

Biodiversity Strategy 2020; Bonn challenge and complementary measures such as REDD+ agreements or Market Certification Schemes are reviewed. Further investigations might be conducted to better appraise what challenges related to inventoried data availability (e.g., reliable taxonomical identification), spatial variability (in-field measurements), stakeholder engagement and non-innovative-solving-approaches. Technology limitations may hamper for these indicators achievement. It will also provide some effective entry points linked to policies that promote resilient and sustainable land management under a climate change context can be possible including in mountain areas.

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