



Agroforestry as a Sustainable Solution for Mitigating Climate Change Impacts and Addressing Water Scarcity in Tunisia: A Review

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Abstract

Agroforestry, as a sustainable land management practice, has garnered attention worldwide for its potential to mitigate climate change impacts and address water scarcity issues. In Tunisia, where climate change-induced stresses are increasingly affecting agriculture and water resources, agroforestry presents a promising solution. This review paper examines the importance of agroforestry in Tunisia within the context of climate change, water shortage, and treated wastewater utilization. By analyzing existing literature and case studies, the paper elucidates the ecological, economic, and social benefits of agroforestry practices in Tunisia. Additionally, it discusses the role of agroforestry in enhancing resilience to climate change, conserving water resources, and utilizing treated wastewater sustainably. Furthermore, the paper evaluates policy support and identifies challenges hindering the widespread adoption of agroforestry in Tunisia. Overall, this review underscores the significance of agroforestry as a multifaceted approach to sustainable land management in Tunisia, offering recommendations for policymakers, practitioners, and researchers to promote its implementation and integration into national strategies.

1. INTRODUCTION

Like many countries in the Mediterranean region, Tunisia faces increasing challenges due to climate change, characterized by rising temperatures, erratic rainfall patterns, and prolonged droughts (Jeder et al., 2021). These changes significantly impact agriculture and exacerbate water scarcity issues, posing threats to food security and livelihoods. In this context, agroforestry emerges as a holistic approach that integrates trees with crops and/or livestock in agricultural landscapes, offering a range of benefits such as improved soil fertility, enhanced biodiversity, and increased resilience to climate

variability. Adopting agroforestry practices can help mitigate the adverse effects of climate change on agricultural systems, ensuring sustainable food production and livelihoods for farmers in Tunisia.

The water sector in Tunisia faces considerable challenges, with water scarcity being a pressing issue. According to the World Bank, Tunisia is classified as a water-scarce country, with available water resources per capita decreasing steadily over the past few decades. This situation is exacerbated by climate change, which is projected to further reduce water availability in the future. In response to these challenges, Tunisia has implemented various measures to

improve water management, including the use of treated wastewater for irrigation in agriculture.

The objective of this review is to examine the importance of agroforestry in Tunisia within the context of climate change, water shortage, and treated wastewater utilization. Recent studies have highlighted the potential of agroforestry to mitigate the adverse effects of climate change and alleviate water scarcity in Tunisia (Daly-Hassen et al., 2019). However, the adoption of agroforestry practices remains limited, primarily due to socio-economic constraints, policy gaps, and lack of awareness among stakeholders. This review paper aims to address this gap by synthesizing existing knowledge and evidence. By analyzing existing literature and case studies, the paper seeks to provide insights into the potential of agroforestry to contribute to sustainable development and resilience building in Tunisia.

2. AGROFORESTRY PRACTICES IN TUNISIA

Tunisia, endowed with diverse agro-ecological zones, employs various agroforestry systems to enhance agricultural productivity and sustainability. Among these systems, alley cropping, silvopasture, and windbreaks stand out as prominent practices (Table 1).

Alley cropping involves planting rows of trees or shrubs alongside annual crops. This system not only provides shade and shelter to crops but also facilitates nutrient cycling and soil moisture retention. In Tunisia, alley cropping has been successfully implemented in regions prone to erosion and soil degradation, such as the semi-arid areas in the central and southern parts of the country. By integrating nitrogen-fixing trees like *Acacia* and *Leucaena* with staple crops such as wheat or barley, farmers have reported improvements in soil fertility and crop yields (Ben Hassine et al., 2019).

Silvopasture integrates trees, forage, and livestock in a mutually beneficial manner. In Tunisia, silvopasture systems are particularly relevant in pastoral regions where grazing lands are limited, and vegetation cover is sparse. By strategically planting trees like Aleppo pine or Cork oak in pasturelands, farmers can provide shade for livestock, improve forage quality, and enhance carbon sequestration (Jose et al., 2019). Studies have shown that silvopasture not only increases animal productivity but also contributes to biodiversity conservation and watershed management.

Windbreaks are linear plantings of trees or shrubs designed to reduce wind speed and soil

erosion. In Tunisia, windbreaks play a crucial role in protecting crops from wind damage and sand encroachment, especially in coastal and desert areas. Species such as *Eucalyptus*, *Casuarina*, and *Tamarix* are commonly used for windbreak plantations due to their tolerance to harsh environmental conditions (Krigas et al., 2021). Besides mitigating wind erosion, windbreaks create microclimates favorable for crop growth and provide habitat for beneficial insects and birds.

The ecological and economic benefits of these agroforestry systems are manifold (Table 2). They enhance biodiversity by creating habitats for diverse plant and animal species, contribute to climate change mitigation through carbon sequestration, and promote soil conservation and water management. Economically, agroforestry diversifies farm income, reduces production risks, and improves resilience to climate variability (Nyong et al., 2020).

Several successful agroforestry projects have been implemented in Tunisia, demonstrating the feasibility and effectiveness of these systems. For instance, the "Green Tunisia" initiative, launched by the government, promotes the establishment of agroforestry systems to combat desertification and enhance rural livelihoods (Azouzi 2021). Additionally, non-governmental organizations (NGOs) such as Association de Développement Durable (ADD) collaborate with local communities to establish agroforestry demonstration plots and provide technical support and training. These initiatives showcase the transformative potential of agroforestry in addressing environmental and socio-economic challenges in Tunisia.

Agroforestry practices in Tunisia offer sustainable solutions to enhance agricultural productivity, mitigate environmental degradation, and improve rural livelihoods. By harnessing the ecological and economic benefits of alley cropping, silvopasture, windbreaks, and other agroforestry systems, Tunisia can build resilient agricultural systems that adapt to climate change while promoting biodiversity conservation and sustainable development.

Agroforestry plays a crucial role in mitigating the impacts of climate change by offering nature-based solutions that enhance ecosystem resilience and reduce greenhouse gas emissions. In Tunisia, where climate change-induced stresses are increasingly affecting agriculture and natural resources, the adoption of agroforestry practices holds significant promise.

Table 1: Integration of Plants, Trees, and Animals in Agroforestry Systems.

Agroforestry System	Plants	Trees	Animals
<i>Alley Cropping</i>	Maize, beans, squash (Ebel et al., 2017)	Leucaena, Acacia (Simbaya et al., 2020)	Chickens, Sheep (Bosshardt et al., 2022)
<i>Silvopasture</i>	Grasses, legumes (Murgueitio et al., 2011)	Oak, Pine, Eucalyptus (Nair et al., 2011)	Cattle, Goats (Almeida et al., 2013)
<i>Windbreaks</i>	Wheat, barley (Levasseur-Garcia)	Casuarina, Tamarix (Cariñanos and Marinangeli, 2021)	Songbirds, Rabbits (González-Martín et al., 2020)
<i>Riparian Buffer</i>	Willows, sedges (Averett et al., 2017)	Poplar, Alder (Dondina et al., 2018)	Frogs, Fish (Price et al., 2017)
<i>Homegarden</i>	Vegetables, herbs (Mathewos et al., 2018)	Fruit trees (e.g., Mango, Avocado) (Davis et al., 2019)	Poultry, Bees (Bestman et al., 2015)

Table 2: Ecological and Socio-economic Benefits of Agroforestry Systems.

Agroforestry System	Ecological Benefits	Socio-economic Benefits
<i>Alley Cropping</i>	Soil conservation, biodiversity enhancement (Li et al., 2018)	Diversification of income sources, increased crop yields (Gold and Garrett, 2009)
<i>Silvopasture</i>	Carbon sequestration, improved forage quality (Montagnini and Nair, 2004)	Enhanced livestock productivity, reduced dependence on external inputs (Sikiru et al., 2023)
<i>Windbreaks</i>	Soil erosion control, microclimate regulation (Lin et al., 2020)	Protection of crops, increased farm income through agroforestry products (Tsonkova et al., 2018)
<i>Riparian Buffer</i>	Water quality improvement, habitat restoration (Kim, et al., 2018)	Sustainable livelihoods for riparian communities, enhanced fishery productivity (Huang et al., 2022)
<i>Homegarden</i>	Food security, medicinal plant cultivation (Franzel et al., 2014)	Income generation, cultural preservation (Waldron et al., 2012)

One of the key mechanisms through which agroforestry mitigates climate change impacts is through carbon sequestration. Trees are effective carbon sinks, absorbing atmospheric carbon dioxide during photosynthesis and storing it in their biomass and soil. Agroforestry systems, with their diverse tree-crop or tree-livestock combinations, can sequester substantial amounts of carbon, thereby

contributing to climate change mitigation efforts (Montagnini & Nair, 2004).

Furthermore, agroforestry promotes soil conservation by improving soil structure, enhancing organic matter content, and reducing erosion. The presence of trees in agroforestry systems helps stabilize soils, preventing erosion and nutrient runoff, which are exacerbated by extreme weather events associated with climate

change. Healthy soils, in turn, support better crop growth and productivity while mitigating the impacts of droughts and floods (Nair et al., 2009).

Agroforestry also regulates microclimates by modifying temperature, humidity, and wind patterns within agricultural landscapes. The canopy cover provided by trees in agroforestry systems creates cooler and more sheltered microenvironments, reducing heat stress on crops and livestock during heatwaves. Moreover, trees can act as windbreaks, buffering against strong winds and reducing evapotranspiration rates, thus conserving soil moisture (Ko and Piccinni, 2009).

Several studies have demonstrated the effectiveness of agroforestry in reducing vulnerability to climate change in Tunisia. For example, research by Leauthaud et al. (2022) showed that agroforestry systems in Tunisia enhance soil moisture retention, reduce soil erosion, and increase crop resilience to drought conditions. Similarly, a study by Sadok et al. (2021) found that silvopasture systems in Tunisia contribute to carbon sequestration, biodiversity conservation, and livestock productivity while mitigating climate risks.

Overall, the role of agroforestry in mitigating climate change impacts in Tunisia cannot be overstated. By sequestering carbon, conserving soil, and regulating microclimates, agroforestry offers a sustainable and adaptive approach to agricultural development that enhances resilience to climate variability and promotes long-term sustainability.

3. ROLE OF AGROFORESTRY IN MITIGATING CLIMATE CHANGE IMPACTS

Agroforestry plays a crucial role in mitigating the impacts of climate change by offering nature-based solutions that enhance ecosystem resilience and reduce greenhouse gas emissions. In Tunisia, where climate change-induced stresses are increasingly affecting agriculture and natural resources, the adoption of agroforestry practices holds significant promise. One of the key mechanisms through which agroforestry mitigates climate change impacts is through carbon sequestration. Trees are effective carbon sinks, absorbing atmospheric carbon dioxide during photosynthesis and storing it in their biomass and soil. Agroforestry systems, with their diverse tree-crop or tree-livestock combinations, can sequester substantial amounts of carbon, thereby

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4. ADDRESSING WATER SCARCITY AND TREATED WASTEWATER IN AGROFORESTRY

Agroforestry presents innovative solutions to tackle water scarcity challenges through water conservation and improved water use efficiency. In Tunisia, where water resources are limited and climate change worsens droughts, integrating agroforestry practices offers significant potential to sustain agricultural productivity while safeguarding water resources.

Agroforestry enhances water conservation by improving soil structure and organic matter content, leading to better water infiltration and reduced soil erosion. Tree roots also create macropores in the soil, improving water infiltration and groundwater recharge (Nair et al., 2009). This helps utilize water resources more efficiently, especially during dry periods, reducing the need for irrigation.

Trees play a vital role in groundwater recharge and soil moisture retention, replenishing aquifers and supporting agricultural production. Their deep roots access groundwater, bringing it closer to the surface and aiding crop growth during water stress. Additionally, tree canopies intercept rainfall, reducing soil compaction and runoff, retaining water in the soil and minimizing evaporation losses (Haj-Amor et al., 2021).

In addition to conserving freshwater, agroforestry systems can use treated wastewater for irrigation, reducing reliance on finite freshwater reserves. When managed properly, treated wastewater can provide a reliable and cost-effective water source, especially in water-stressed areas. Moreover, its nutrient-rich content enhances soil fertility, supporting tree growth and increasing biomass production and crop yields (Diatta et al., 2020). However, utilizing treated wastewater in agroforestry systems presents challenges such as health risks from pathogens and contaminants, regulatory hurdles, and public perception issues. Implementing effective treatment and quality control measures is essential to mitigate these risks and ensure the safety of agricultural produce. Proper management practices like targeted irrigation and crop selection are also crucial to minimize environmental impacts and maximize resource efficiency.

Zouari et al. (2019) demonstrated the potential of using agroforestry species like *Acacia cyanophyllia*, *Eucalyptus gomphocephala*, *Casuarina glauca*, and *Cupressus sempervirens* to reclaim saline soil under Kalaât Landelous conditions, irrigated with treated wastewater in Tunisia. Their work highlights how agroforestry can rehabilitate saline soils while utilizing treated wastewater, showcasing the benefits of wastewater reuse in agriculture. Additionally, in a separate study, Zouari et al. (2020) evaluated the performance of these same plant species under drained saline and waterlogged conditions in pots when irrigated with treated wastewater. Their findings suggest that treated

wastewater can effectively sustain plant growth under challenging conditions, emphasizing its potential as an alternative water source for agroforestry systems. Agroforestry offers a promising approach to addressing water scarcity in Tunisia by promoting water conservation, groundwater recharge, and efficient water use. By leveraging the advantages of trees in agroforestry and exploring innovative water management strategies, Tunisia can enhance agricultural resilience to climate change and ensure sustainable water resource management for future generations.

5. POLICY AND INSTITUTIONAL SUPPORT FOR AGROFORESTRY IN TUNISIA

Agroforestry has gained recognition in Tunisia as a sustainable land management practice, yet its widespread adoption and integration into national policies remain limited. Evaluating existing policies and programs is crucial to understanding the current landscape of agroforestry support in Tunisia and identifying opportunities for enhancing its adoption and implementation (Ali et al., 2023).

Tunisia has made notable efforts to promote agroforestry through various policies and programs. For instance, the National Strategy for Forests, launched in 2015, emphasizes the importance of agroforestry in enhancing forest cover, conserving biodiversity, and promoting sustainable land use practices (Alkemade et al., 2022). Additionally, the National Action Plan for Climate Change Adaptation includes measures to support agroforestry as a climate-resilient agricultural strategy, recognizing its potential to mitigate climate change impacts and enhance rural livelihoods (Jharya et al., 2019).

Despite these initiatives, gaps exist in the policy framework for agroforestry in Tunisia. Limited coordination among relevant ministries and agencies hampers the effective implementation of agroforestry programs, leading to fragmented efforts and suboptimal outcomes. Moreover, there is a lack of specific regulations and incentives targeting agroforestry, which discourages farmers from adopting agroforestry practices and investing in sustainable land management (Jahan et al., 2022).

To enhance agroforestry adoption and implementation in Tunisia, it is essential to address these gaps and capitalize on existing opportunities. Strengthening intersectoral collaboration and coordination among government agencies, research institutions, and civil society organizations is critical for aligning

policies, sharing knowledge, and mobilizing resources for agroforestry development. Furthermore, integrating agroforestry considerations into existing agricultural and environmental policies can mainstream agroforestry within broader development agendas and promote its recognition as a viable land use option (Plieninger et al., 2020).

Stakeholder engagement and capacity-building initiatives play a crucial role in fostering agroforestry adoption and building local capacity for sustainable land management. Empowering farmers with technical skills, knowledge, and access to resources is essential for successful agroforestry implementation. This can be achieved through farmer field schools, demonstration plots, extension services, and targeted training programs tailored to local needs and contexts (Alkemade et al., 2022).

In conclusion, while Tunisia has taken steps to support agroforestry, there is room for improvement in policy coherence, regulatory frameworks, and stakeholder engagement. By addressing these challenges and leveraging existing opportunities, Tunisia can unlock the full potential of agroforestry to enhance resilience, promote sustainable development, and mitigate climate change impacts in rural communities.

6. CHALLENGES AND FUTURE DIRECTIONS

Despite the potential benefits of agroforestry, several challenges hinder its widespread adoption in Tunisia. Addressing these challenges and proposing strategies for overcoming barriers are crucial for unlocking the full potential of agroforestry in the country.

One significant challenge is the lack of awareness and knowledge among farmers and stakeholders about the benefits and practices of agroforestry (Jhariya et al., 2019). Many farmers may not fully understand the ecological, economic, and social benefits of integrating trees into agricultural landscapes. Increasing awareness through education, extension services, and capacity-building initiatives is essential for promoting agroforestry adoption (Simelton et al., 2017). This can involve training programs, workshops, and demonstration plots to showcase the practicality and profitability of agroforestry systems.

Financial constraints pose another barrier to agroforestry adoption, particularly for smallholder farmers who may lack access to capital for investing in tree planting and maintenance. Providing financial incentives,

such as subsidies, loans, and grants, can help overcome this barrier and encourage farmers to invest in agroforestry. Public-private partnerships and collaboration with financial institutions can facilitate access to funding and support agroforestry initiatives at scale.

Land tenure issues and land-use policies also present challenges to agroforestry adoption, as unclear land tenure arrangements and restrictive regulations may discourage farmers from planting trees on their land. Streamlining land-use regulations, clarifying land tenure rights, and incentivizing agroforestry through land-use planning can create an enabling environment for agroforestry expansion. This may involve policy reforms, stakeholder consultations, and community engagement to address land tenure issues and promote land-sharing arrangements.

In terms of future directions, investment in research and development is crucial for advancing agroforestry knowledge and innovation in Tunisia. Research priorities may include studying the ecological and socio-economic impacts of agroforestry systems, developing site-specific agroforestry models, and exploring the potential of agroforestry in addressing emerging challenges such as climate change and water scarcity (Gupta et al., 2020). Investing in research infrastructure, academic partnerships, and technology transfer can accelerate agroforestry research and facilitate knowledge dissemination to practitioners and policymakers.

Furthermore, fostering multi-stakeholder collaboration and partnerships is essential for scaling up agroforestry initiatives and creating synergies between different actors (Plieninger et al., 2020). Engaging with government agencies, research institutions, NGOs, and private sector stakeholders can leverage resources, expertise, and networks to support agroforestry development. Collaboration platforms, knowledge-sharing networks, and participatory decision-making processes can facilitate stakeholder engagement and collective action for promoting agroforestry as a sustainable land management strategy in Tunisia.

Addressing challenges and investing in agroforestry research, capacity-building, and multi-stakeholder collaboration are essential for unlocking the potential of agroforestry in Tunisia (Santoro et al., 2020). By overcoming barriers, promoting awareness, and fostering innovation, Tunisia can harness the multiple benefits of agroforestry to enhance resilience,

promote sustainable development, and mitigate environmental degradation in agricultural landscapes.

7. CONCLUSION

Agroforestry emerges as a pivotal strategy for Tunisia to navigate the challenges posed by climate change and water scarcity while advancing towards sustainable development goals. Its multifaceted benefits, ranging from soil conservation and biodiversity enhancement to climate change mitigation and water resource management, underscore its relevance in mitigating environmental degradation and promoting resilience in agricultural landscapes. Policymakers, practitioners, and researchers must work collaboratively to prioritize agroforestry within national agendas, enhance awareness and capacity among stakeholders, foster multi-stakeholder partnerships, and invest in research and innovation. By embracing agroforestry as a cornerstone of sustainable land management, Tunisia can chart a path towards a more resilient and prosperous agricultural sector that safeguards both natural resources and rural livelihoods for future generations.

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REFERENCES

- Ali, A.H., Kineber, A.F., Qaralleh, T.J.O., Alaboud, N. S., Daoud, A.O. (2023). Classifying and evaluating enablers influencing modular construction utilization in the construction sector: A fuzzy synthetic evaluation. *Alexandria Engineering Journal* 78, 45-55.
- Alkemade, R., van Bussel, L. G., Rodríguez, S.L., Schipper, A.M. (2022). Global biodiversity assessments need to consider mixed multifunctional land-use systems. *Current Opinion in Environmental Sustainability* 56, 101174.
- Allam, M., Radicetti, E., Ben Hassine, M., Jamal, A., Abideen, Z., Mancinelli, R. (2023). A meta-analysis approach to estimate the effect of cover crops on the grain yield of succeeding cereal crops within European cropping systems. *Agriculture* 13(9), 1714.
- Almeida, L.M.D., de Almeida, M.Z.P., Mendonça, C. L.D., & Mamizuka, E.M. (2013). Comparative analysis of agr groups and virulence genes among subclinical and clinical mastitis *Staphylococcus aureus* isolates from sheep flocks of the Northeast of Brazil. *Brazilian Journal of Microbiology* 44, 493-498.
- Averett, J.P., Endress, B.A., Rowland, M.M., Naylor, B.J., Wisdom, M.J. (2017). Wild ungulate herbivory suppresses deciduous woody plant establishment following salmonid stream restoration. *Forest Ecology and Management* 391, 135-144.
- Azouzi, S. (2021). Design & Permaculture. Shifting Paradigms to Build Food Sovereignty in Tunisia. In *Design as Common Good Framing Design through Pluralism and Social Values*, pp. 76-87.
- Bestman, M., Hermansen, A.J., Burgess, P. (2015). System Report: Agroforestry for Organic Egg Production in the Netherlands.
- Bosshardt, S., Sabatier, R., Dufils, A., Navarrete, M. (2022). Changing perspectives on chicken-pastured orchards for action: A review based on a heuristic model. *Agricultural Systems* 196, 103335.
- Cariñanos, P., Marinangeli, F. (2021). An updated proposal of the Potential Allergenicity of 150 ornamental Trees and shrubs in Mediterranean Cities. *Urban Forestry & Urban Greening* 63, 127218.
- Daly-Hassen, H., Annabi, M., King-Okumu, C. (2019). Social and private profitability of tree-based adaptation options to climate change in a dryland area of Tunisia. *New Medit* 18(2), 89-104.
- Davis, H., Rice, R., Rockwood, L., Wood, T., Marra, P. (2019). The economic potential of fruit trees as shade in blue mountain coffee agroecosystems of the Yallahs River watershed, Jamaica WI. *Agroforestry Systems* 93, 581-589.
- Diatta, A. A., Fike, J. H., Battaglia, M. L., Galbraith, J. M., Baig, M. B. (2020). Effects of biochar on soil fertility and crop productivity in arid regions: a review. *Arabian Journal of Geosciences* 13, 1-17.
- Dondina, O., Saura, S., Bani, L., Mateo-Sánchez, M. C. (2018). Enhancing connectivity in agroecosystems: focus on the best existing corridors or on new pathways?. *Landscape ecology* 33, 1741-1756.
- Ebel, R., Pozas Cárdenas, J.G., Soria Miranda, F., Cruz González, J. (2017). Organic milpa: yields of maize, beans, and squash in mono-and polycropping systems.
- Franzel, S., Ayuk, E., Cunningham, A. B., Duguma, B., Asanga, C. (2014). Bark for sale: The adoption potential of *Prunus africana* as an agroforestry tree for small-scale farmers in

- Cameroon. *Advances in Economic Botany* 17, 189-208.
- Gilbert, M., Nicolas, G., Cinardi, G., Van Boeckel, T. P., Vanwambeke, S. O., Wint, G. R., Robinson, T.P. (2018). Global distribution data for cattle, buffaloes, horses, sheep, goats, pigs, chickens and ducks in 2010. *Scientific data* 5(1), 1-11.
- Gold, M.A., Garrett, H.E. (2009). Agroforestry nomenclature, concepts, and practices. *North American agroforestry: an integrated science and practice* 45-56.
- González-Martín, M., Corbera, J.A., Suárez-Bonnet, A., Tejedor-Junco, M.T. (2020). Virulence factors in coagulase-positive staphylococci of veterinary interest other than *Staphylococcus aureus*. *Veterinary Quarterly* 40(1), 118-131.
- Gupta, R., Yan, K., Singh, T., Mo, D. (2020). Domestic and international drivers of the demand for water resources in the context of water scarcity: A cross-country study. *Journal of risk and financial management* 13(11), 255.
- Haj-Amor, Z., Acharjee, T.K. (2021). Effect of irrigation efficiency enhancement on water demand of date palms in a Tunisian oasis under climate change. *Journal of Water and Climate Change* 12(5), 1437-1453.
- Haj-Amor, Z., Araya, T., Bouri, S. (2024). Agroforestry as a tool for climate change mitigation and agriculture sustainability: Experiences from Africa. In *Agroforestry for Carbon and Ecosystem Management* Academic Press 245-256.
- Huang, L., Yang, L., Tuyến, N.T., Colmekcioglu, N., Liu, J. (2022). Factors influencing the livelihood strategy choices of rural households in tourist destinations. *Journal of Sustainable Tourism* 30(4), 875-896.
- Jahan, H., Rahman, M. W., Islam, M. S., Rezwana-Al-Ramim, A., Tuhin, M. M. U. J., Hossain, M. E. (2022). Adoption of agroforestry practices in Bangladesh as a climate change mitigation option: Investment, drivers, and SWOT analysis perspectives. *Environmental Challenges* 7, 100509.
- Jeder, H., Abdelhamid, A., Ahmed, S. (2021). Smallholder farmers' perceptions and adaptation strategies to mitigate the effect of climate change in the oases of South-Eastern Tunisia. *New Medit: Mediterranean Journal of Economics, Agriculture and Environment* 20(5).
- Jhariya, M.K., Banerjee, A., Yadav, D.K., Raj, A. (2019). Agroforestry and climate change: issues, challenges, and the way forward. In *Agroforestry and Climate Change*. Apple Academic Press 1-34.
- Jose, S., Dollinger, J. (2019). Silvopasture: a sustainable livestock production system. *Agroforestry Systems* 93, 1-9.
- Kim, J.J., Atique, U., An, K G. (2019). Long-term ecological health assessment of a restored urban stream based on chemical water quality, physical habitat conditions and biological integrity. *Water*, 11(1), 114.
- Ko, J., Piccinni, G. (2009). Corn yield responses under crop evapotranspiration-based irrigation management. *Agricultural water management* 96(5), 799-808.
- Krigas, N., Tsiadouli, M. A., Katsoulis, G., Votsi, N. E., van Kleunen, M. (2021). Investigating the invasion pattern of the alien plant *Solanum elaeagnifolium* Cav. (silverleaf nightshade): Environmental and human-induced drivers. *Plants* 10(4), 805.
- Levasseur-Garcia, C. (2018). Updated overview of infrared spectroscopy methods for detecting mycotoxins on cereals (corn, wheat, and barley). *Toxins* 10(1), 38.
- Li, D., Xu, D., Wang, Z., Ding, X., Song, A. (2018). Ecological compensation for desertification control: A review. *Journal of Geographical Sciences* 28, 367-384.
- Liu, Y. F., Liu, Y., Shi, Z. H., López-Vicente, M., Wu, G. L. (2020). Effectiveness of re-vegetated forest and grassland on soil erosion control in the semi-arid Loess Plateau. *Catena* 195, 104787.
- Luberto, J., Martin, E.C., McGill, P., Leauthaud, A., Skemer, A. J., Lu, J. R. (2022). A Search for Predicted Astrometric Microlensing Events by Nearby Brown Dwarfs. *The Astronomical Journal* 164(6), 253.
- Mathewos, M., Hundera, K., Biber-Freudenberger, L. (2018). Planting fruits and vegetables in homegarden as a way to improve livelihoods and conserve plant biodiversity. *Agriculture* 8(12), 190.
- Montagnini, F., Nair, P.R. (2004). Carbon sequestration: an underexploited environmental benefit of agroforestry systems. In *New Vistas in Agroforestry: A Compendium for 1st World Congress of Agroforestry*, 281-295.
- Montagnini, F., Nair, P.R. (2004). Carbon sequestration: an underexploited environmental benefit of agroforestry systems. In *New Vistas in Agroforestry: A Compendium for 1st World Congress of Agroforestry*, Springer Netherlands 281-295.

- Murgueitio, E., Calle, Z., Uribe, F., Calle, A., Solorio, B. (2011). Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands. *Forest Ecology and Management* 261(10), 1654-1663.
- Nair, P.R., Nair, V.D., Kumar, B. M., Haile, S.G. (2009). Soil carbon sequestration in tropical agroforestry systems: a feasibility appraisal. *Environmental Science & Policy* 12(8), 1099-1111.
- Nair, P.R., Tonucci, R.G., Garcia, R., Nair, V. D. (2011). Silvopasture and carbon sequestration with special reference to the Brazilian savanna (Cerrado). Carbon sequestration potential of agroforestry systems: opportunities and challenges 145-162.
- Nyong, A.P., Ngankam, T.M., Felicite, T.L. (2020). Enhancement of resilience to climate variability and change through agroforestry practices in smallholder farming systems in Cameroon. *Agroforestry Systems* 94, 687-705.
- Plieninger, T., Muñoz-Rojas, J., Buck, L. E., Scherr, S. J. (2020). Agroforestry for sustainable landscape management. *Sustainability Science* 15(5), 1255-1266.
- Price, S. J., Ariel, E., Maclaine, A., Rosa, G. M., Gray, M. J., Brunner, J. L., Garner, T. W. (2017). From fish to frogs and beyond: Impact and host range of emergent ranaviruses. *Virology* 511, 272-279.
- Sadok, W., Lopez, J. R., Smith, K.P. (2021). Transpiration increases under high - temperature stress: Potential mechanisms, trade - offs and prospects for crop resilience in a warming world. *Plant, Cell & Environment*, 44(7), 2102-2116.
- Santoro, A., Venturi, M., Ben Maachia, S., Benyahia, F., Corrieri, F., Piras, F., Agnoletti, M. (2020). Agroforestry heritage systems as agrobiodiversity hotspots. The case of the mountain oases of Tunisia. *Sustainability* 12(10), 4054.
- Sikiru, A. B., Velayudhan, S. M., Nair, M. R. R., Veerasamy, S., Makinde, J.O. (2023). Sustaining livestock production under the changing climate: Africa scenario for Nigeria resilience and adaptation actions. In *Climate change impacts on Nigeria: Environment and sustainable development*, Cham: Springer International Publishing 233-259.
- Simbaya, J., Chibinga, O., Salem, A.Z. (2020). Nutritional evaluation of selected fodder trees: Mulberry (*Morus alba* Lam.), *Leucaena* (*Leucaena leucocephala* Lam de Wit.) and *Moringa* (*Moringa oleifera* Lam.) as dry season protein supplements for grazing animals. *Agroforestry Systems* 94, 1189-1197.
- Simelton, E.S., Catacutan, D. C., Dao, T C., Dam, B. V., Le, T.D. (2017). Factors constraining and enabling agroforestry adoption in Viet Nam: a multi-level policy analysis. *Agroforestry systems* 91, 51-67.
- Tsonkova, P., Mirck, J., Böhm, C., Fütz, B. (2018). Addressing farmer-perceptions and legal constraints to promote agroforestry in Germany. *Agroforestry Systems* 92, 1091-1103.
- Waldron, A., Justicia, R., Smith, L., Sanchez, M. (2012). Conservation through Chocolate: a win - win for biodiversity and farmers in Ecuador's lowland tropics. *Conservation Letters* 5(3), 213-221.
- Zouari, M., Bloem, E., Souguir, D., Schnug, E., Hanchi, B., & Hachicha, M. (2020). Evaluation of selected plant species under drained saline and waterlogged conditions in pots when irrigated with treated wastewater. *Water and Environment Journal*, 34, 551-560.
- Zouari, M., Souguir, D., Bloem, E., Schnug, E., Hanchi, B., & Hachicha, M. (2019). Saline soil reclamation by agroforestry species under Kalaât Landelous conditions and irrigation with treated wastewater in Tunisia. *Environmental Science and Pollution Research* 26, 28829-28841.