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Agroforestry and Soil Salinity Management in the Aral Sea Basin, Uzbekistan.

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Abstract

Land degradation caused by salinity is common in arid and semi-arid regions across the globe, where agriculture is difficult to sustain without a proper irrigation. On the other hand, secondary salinization, which is also caused by poor agricultural management, impacts enormous lands with varying degrees of soil salinity. In the Aral Sea Basin, increased soil salinity has resulted in widespread land damage. In general, Uzbekistan is one of the nations with a high proportion of salinized soil. Although the quantity of saline land varies, areas in the lower parts of the Amudarya river are the most salinized, accounting for more than 90% of all irrigated land. This discrepancy is attributed to the hydrogeological characteristics of downstream parts of the Amudarya river, particularly in Khorezm and Karakalpakstan, which are situated in low accumulative plains with poorly drained alluvial lowlands, making these places prone to salinization. Agroforestry is commonly a financially viable land-use option for the environmental rehabilitation of salinized cropping fields in irrigated drylands, but farm-level afforestation programs face a number of socio-political constraints. The results highlighted in the paper show that the importance of farmer risk perceptions in making choices regarding alternative land use adoption varies. Overall, the study enables the identification of policy incentives for afforestation that may have a direct influence on the decision-making of prospective stakeholders. It is clear from the review that there is an urgent need for better land-use flexibility, improved land tenure and tree plantation ownership security, more agroforestry knowledge and training, and increased institutional assistance especially in marginal environments.

Keywords: salinity, agroforestry, Aral Sea, land use options, marginal environment

Introduction, scope and main objectives

It is estimated that irrigated agriculture in the Aral Sea Basin (ASB) uses more than 90 percent of the available water resources and produces around 30 percent of the region's gross domestic product (GDP), giving employment to more than 60 percent of the region's population. Supplies from the Amudarya and Syrdarya Rivers, both of which are tributaries of the Aral Sea, meet the majority of the agricultural water needs in the region. Dried-up Aral Sea due to decades of extensive irrigation and poor drainage (Micklin, 2016) is considered a main cause of current problems. Because of salinity, around 20% of cotton harvests in the ASB have been lost, causing in annual financial losses of more than US$ 200 million for the cotton industry (CISEAU, 2006). Furthermore, climate change projections for the ASB include temperature rises of 3–4 degrees Celsius. Annual temperature increases have generated an increase in potential evapotranspiration in Central Asia (Lioubimtseva and Henebry, 2009), which is expected to result in a further 30 percent drop in agricultural yields, resulting in negative socio-economic consequences. Aspects of land degradation that are particularly prevalent in the country include secondary salinization in irrigated fields, soil erosion in rain-fed and hilly parts of the country, and loss of vegetation, desertification, or a negative shift in the mix of flora in rangelands (Gupta et al. 2009). Land degradation in the area is caused by a variety of factors that are very complicated and interconnected (Pender et al. 2009). In addition to unsustainable agricultural methods, the expansion of crop production into fragile and marginal areas, insufficient maintenance of irrigation and drainage networks, and overgrazing near communities are also contributing factors (Kienzler et al. 2012). It is well acknowledged that desert salinity and the poor quality of related water in the Aral Sea Basin's peripheral desert belt are among the most serious natural resource degradation concerns not only for the country but also for Central Asian region.

The availability of irrigation water in this area has declined dramatically in recent years, posing further challenges to rangeland productivity and agricultural output (Lamers et al. 2005). The practice of afforestation has been shown to be effective in revegetating arid landscapes, providing valuable products to local pastoral communities from marginal degraded land, and making use of otherwise low-quality water, unproductive lands, and decreasing the elevated groundwater table through biodrainage (Khamzina et al. 2006). However, in order to achieve successful and long-term results, afforestation of marginal areas must be preceded by a thorough assessment of the suitability of both native and imported tree species. The use of natural vegetation and revegetation plays a critical role in the production of oasis agriculture in salty areas, according to Gupta et al. (2009). Considering climate change, it is critical and essential to understand the regional agroforestry status, provide chances for continued promotion to meet climate commitments, and ensure that agroforestry methods are accepted successfully.

The purpose of this study is to provide an overview of the current research on agroforestry methods and their contribution to socio-economic and ecological development.

Methodology/approach

In light of this background, the study carries out a comprehensive evaluation of online publication databases to acquire a clear picture of the potential role of agroforestry systems in marginal environments of Central Asia and in particular in Uzbekistan. This study also analyzes the a critical awareness of important gap areas, current legislation, and challenges that require particular attention.

To determine the extent of knowledge about Agroforestry initiatives in the study area, a bibliometric analysis were conducted. The keywords "Agroforestry", “Salinity”, “Aral Sea”, “Uzbekistan” and “Central Asia” turned up relevant 62 published articles in the reviewed databases which were from 1991 to 2021. Metadata connected with papers may be analyzed to learn more about the research's overall structure and main points. Conservation, agroforestry, biodiversity, and soil management are the most often occurring author keywords, according to a frequency analysis of those terms. Central Asia's overarching subject of agroforestry encompasses themes like as conservation and biodiversity, agricultural management, biomass, carbon sequestration, and climate change mitigation and adaptation. Socio-economic factors including local people's livelihoods and changing farming were also given special attention in the paper.

Results

In the same way, past studies have just minimally taken into consideration the economic, social, and environmental components of the salinization issue in their overall study. In the past, classic steady-state and transient models were mostly used for modeling the influence of drain spacing and depth on the amount of drainage effluent produced (e.g., Ren et al., 2019; Sands et al., 2015). Liang et al. (2018) and Skaggs et al. (2014) have both employed models to predict the nutrient dynamics and soil moisture progression under a tile drainage network to great success. While some other models were focused on increasing the efficiency with which water was used in agricultural output and on controlling salinization in dry regions, others were focused on improving the efficiency with which water was used in urban areas (e.g., Li et al., 2020). These models, on the other hand, seldom took into account the farmer's reactions to salinization and waterlogging. Including farmer input in an irrigation model should be done in such a manner that the model is able to progressively decrease the amount of irrigation water used as soil salinity rises and the water table grows shallower.

According to Huang et al. (2012), the majority of current optimization models are focused on one single goal, such as maximization of the economic benefits of the system under a given set of circumstances. However, given the multifaceted nature of salinization and waterlogging issues, it is recommended that prospective modeling frameworks take into account different goals, such as enhancing economic advantages, lowering environmental degradations, and boosting water productivity, among others. Additionally, the integration of several algorithms, such as linear and nonlinear, into an outlook model is recommended in order to reap the benefits of their explicit advantages. Because a linear model's structure is simple, its learning expense is modest, and it has excellent operating efficiency, it is a good choice for many applications. A nonlinear model, on the other hand, may improve the overall performance of the system by properly tackling complicated issues. In earlier research (e.g., Fathizad et al., 2020;), large-scale mapping of soil salinization and waterlogged regions was mostly accomplished by the use of remote sensing and geographic information systems (GIS) methods. In the majority of past research, it has been observed that the combined applications of these approaches are more beneficial than the individual applications of these techniques (e.g., Gorji et al., 2017). These approaches have also been extensively used in modeling frameworks for soil salinity mapping, which is a relatively new field (Asfaw et al., 2018). The bulk of these research have relied on remote sensing and geographic information system (GIS) methods to map the influence of subsurface waterlogging on surface soil moisture using an indirect methodology. Poor farmers, on the other hand, are unable to afford the substantial initial expenditure necessary for the installation of a drip irrigation system. As a result, authorities should develop and execute more effective methods to encourage and support such projects at the regional level. Adequate financing is also required for improved drainage and other infrastructure improvements in order to cope with the salinization and waterlogging issues that are now being experienced. Several studies have shown that forests and trees play an essential role in the modulation of global, regional, and local hydrological cycles and patterns (Filoso et al. 2017; Ellison et al. 2012).

This bio-drainage option necessitates the strategic placement of trees throughout the landscape (possibly in conjunction with conventional drainage facilities) in order to achieve effective salinity control, which is incompatible with the criteria used for spatial targeting of afforestation on marginal land (Dubovyk et al. 2016; Kumar et al. 2019).

The increased productivity of marginal cropland planted with salt-tolerant tree species capable of utilizing relatively untapped groundwater resources is still a viable option for managing salinized croplands, even if reductions in soil salinity through afforestation are not anticipated in the study region. Agroforestry offers a variety of approaches that can provide beneficial effects for conservation and for livelihoods.

Discussion

While the severity of land degradation in Central Asia has been well acknowledged, there has been a paucity of published research attempting to quantify the amount of land degradation in the area by analyzing observable data at national or regional dimensions (Ji 2008). A rising number of localized case studies, based on extensive soil surveys or remote sensing data, are being published (e.g. Dubovyk et al. 2013; Akramhanov et al. 2011; Akramhanov and Vlek 2012).

Salinization is the most serious land degradation issue in the irrigated parts of the region, accounting for 40–60 percent of all irrigated lands in the region, according to estimates published in Qadir et al. (2009). Traditionally, farmers have attempted to combat salt by leaching the soil; however, the use of more saline irrigation water impairs the efficiency of leaching and contributes to the issue of excessive water usage (Pender et al. 2009).

Many studies in the Amudarya and Syrdarya Basins (Conrad et al., 2013; Tischbein et al., 2013) have demonstrated the importance of increasing the efficiency of irrigation water use in the face of rising evapotranspiration, precarious annual water supplies, and salt load (Varis, 2014). This is especially true in the heavily affected downstream areas of the Amudarya and Syrdarya. A proposal to remove very salty, marginally productive areas from irrigated crops and replace them with salt-tolerant, multi-purpose tree species has been made in order to improve the efficiency of water resources management in the lower Amudarya (Khamzina, 2006). As a result of their effective use of saline groundwater, trees have reduced their need on irrigation to just 10 percent to 30 percent of the total agricultural irrigation requirements (Khamzina et al., 2009).

The restoration of damaged croplands helps to the conservation of irrigation water that may be transferred to productive farmland regions, enabling the production of water-intensive commercial crops while a variety of tree-based products are produced. Basin and furrow irrigation technologies are used to water the crops in the field. A large amount of water, 25 percent to 30 percent of the total yearly consumption, is needed for salt leaching in late February and early March, prior to the sowing of cotton according to Ibrakhimov et al. (2008). Drainage networks collect and carry leached effluent outside of the farmland area in order to regulate increasing groundwater levels and avoid soil salinization.

Awan et al. (2011) found that these drainage practices are only moderately effective, given the high-water inputs through irrigation losses and leaching into groundwater, as well as outlet problems and insufficient capacity of the drainage canals in terms of depth and spacing, which is exacerbated by poor maintenance of the infrastructure. Increased groundwater tables and soil salinity continue to exist as a result of limited leaching efficacy and fast salt buildup due to capillary rise (Ibrakhimov et al., 2007). Insufficient and ill-timed water delivery in farmlands situated at the lower reaches of the irrigation network (Olimjanov and Mamarasulov, 2006; Conrad et al., 2007) results in a larger salt load than farmlands located at the upper reaches of the irrigation network (Ibrakhimov et al., 2007). It has been shown that dryland afforestation has negative hydrological implications, such as the depletion of soil water and the reduction of annual runoff and water yields (Djanibekov et al. 2013; Norgaard 2005), particularly in large-scale plantation programs (Noorgaard 1988; Fischer et al. 2007). For example, in Khorezm (Romer 2005), where excessive agricultural irrigation is practiced, the decrease in all analyzed water balance components after the afforestation of marginal land reflects the reduction in irrigation inputs and the reduction in drainage output. It is anticipated that these effects will have favorable consequences for irrigation water conservation (Hagg et al. 2013) and reduction of increased groundwater tables (Juldashev and Messerli 2000).

Irrigated regions in the downstream nations of Central Asia, where water consumption rates are among the highest in the world and irrigation water-use efficiency and water productivity remain low, are in desperate need of water-saving methods. Planting trees on marginal farmland, which would otherwise be planted with low-yielding and water-intensive crops, has many benefits for maintaining long-term irrigated agricultural production. This is especially desired given the fact that climate change is increasing the precarity of water resources and sharpening competition for water in the transboundary Amudarya Basin, among other things.

It is unlikely that a significant reduction in water balance component values (while beneficial in terms of reducing irrigation water losses in the region) will result in dramatic decreases in soil moisture and groundwater levels, which would have jeopardized the long-term sustainability of crop and tree water use in the study area.

In light of the low yields of common crops compared to the high production value of trees on marginal land, as well as the possibility of utilizing water savings from afforestation for the cultivation of alternative, commercially attractive crops on productive cropland , this land use conversion would result in financial gains.

Afforestation of degraded croplands in Central Asia has the potential to enhance low forest cover, particularly in downstream regions dominated by annual crops, while not competing for crop production on prime agricultural land.

The purposeful use of tree planting (bio-drainage) in other irrigated drylands that are undergoing soil salinization, such as India and Australia, has been shown to be an effective technique for regulating increased groundwater levels and soil salinization.

Conclusions/ wider implications of findings

In spite of this, there are significant advantages from Agroforestry that have yet to be tapped at the local or national level. A country-level regional agreement is essential for mainstreaming agroforestry. National pledges to accept and recognize the advantages of AFS under national agroforestry programs are a crucial next step, phase-wise implementation is needed. Priority should be establishing a realistic goal of restoring deteriorated agroforestry and improving the systems by 50% during the next five years. To keep the momentum on moving forward with agroforestry initiatives, we need to do more than just to raise awareness and provide technical assistance. We need to address local livelihood needs and provide new possibilities. Enhancing the agricultural productivity of forest dependent disadvantaged groups and farmers by adopting improved inputs, new technology and incentives to boost agricultural intensification and livelihood diversification will assist achieve objectives and make progress on numerous SDGs.

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