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Opinion

Agricultural Land Use Change Options and Climate Change

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The natural growth of the population inevitably leads to rapid urbanization, which is presently one of the dynamic and serious issues. Urban sprawl converts forest and farming lands into urban lands, leading to the decrease of arable forming lands and economic forest lands, which presents the threat to the food security, lumber industry and environment for human beings Wu and Oueslati [1]. In the US, there is an annual conversion of 500,000 ha away from food and fiber production systems. Coupled with a one percent annual population increase, this will reduce today's allocation of 0.6 ha per person to 0.3 ha by 2050 Francis et al. [2]. Besides economic impacts, the environmental quality is also significantly affected Bhattarai et al. [3], Thomas and Sporton [4]; Walsh et al. [5]. Both field observations and simulative and numerical analysis suggest that urban growth-driven land-use changes significantly influence the surface heat balance, exchange of water vapor and momentum between the atmosphere and the surface layer, and consequently results in the changes of the environment Vadrevu et al. [6]; Vlachogiannis et al. [7]. Most importantly, with decreased farming lands, agricultural practices are expected to be intensified including increased use of fertilizers in order to boost productivity. This eventually results in aggravated environmental impacts in terms of water contamination and greenhouse gas emission, which ultimately will lead to climate change. Climate change studies have documented clear warming trends globally, which results in higher surface temperatures. Global average surface temperature increased by about 0.74°C during the 20th century; over the next 40 years, the average US temperature is projected to increase by 1–2°C, with increase of 2–3°C in the interior Lysak and Bugge-Henriksen [8].

This change in temperature will likely lead to increased precipitation, with the increase of temperature more pronounced than that of precipitation (Figure 1). Rainfall patterns are projected to change in different ways in different geophysical locations of the US Halder et al. [9]; Ouyang et al. [10]. For example, summertime precipitation in the northwestern US is predicted to decrease by 15–25%, while the northern central and eastern US will see an increase of 5-15%. In contrast, winter precipitation is projected to increase by 5–15% in the northern and central US, but decrease by 5-10% along the southern US border Portmann et al. [11], Wang et al. [12]. Higher surface temperatures and more variable precipitation are expected because of the climate change, which will negatively impact the natural resources Masters [13]; Paudel and Hatch [14]; Schlenker et al. [15]. Climate change can also affect a wide range of environmental and landscape attributes, including water resources, soil erosion, soil and water quality, ecosystem processes and services, and the climate itself through greenhouse gas (GHG) fluxes and surface albedo effects Wallace et al. [16]. Effective land-use changes can mitigate these impacts, with the scale of mitigation extending from local to regional and global (Meiyappan et al., 2014). However, land-use changes may themselves trigger social and economic changes, such as shifts in population, local economic development, and constraints on policy implementation within crop and forest production systems Briner et al. [17]; Rotter et al. [18]; Sands and Edmonds [19]. When land-use changes are implemented for climate change adaptation, community acceptance due to social and economic impacts across multiple services and scales must also be considered.

It is therefore essential to understand the level of impacts of land-use changes induced by urbanization on the economy and environment. Dynamic research should be conducted to characterize land-use changes and their impacts on the environmental quality, human well-being and economy in line with the development of urbanization. Land management has historically focused on increasing the productivity of agroecosystems. The vision now must be broadened to not just increase production but also to manage land in ways that sustain food production, maintain freshwater and forest resources, and regulate climate and air quality Heald and Spracklen, [20]; Hogrefe et al. [21]; Hyman [22]; Perring et al. [23]. Under climate change conditions, suitable land-use changes are required to sustain the ecosystem and to battle the decline in biodiversity due to loss, modification and fragmentation of habitat, degradation of soil and water, and overexploitation of native species Huston [24]. Given the pervasive impacts of climate change, land-use changes must be carefully investigated for their ability to alleviate the vulnerability of the food/fiber supply chain across multiple geographic scales and ecological dimensions. Currently, the following land use types and management practices are of special interest to combat the climate change:

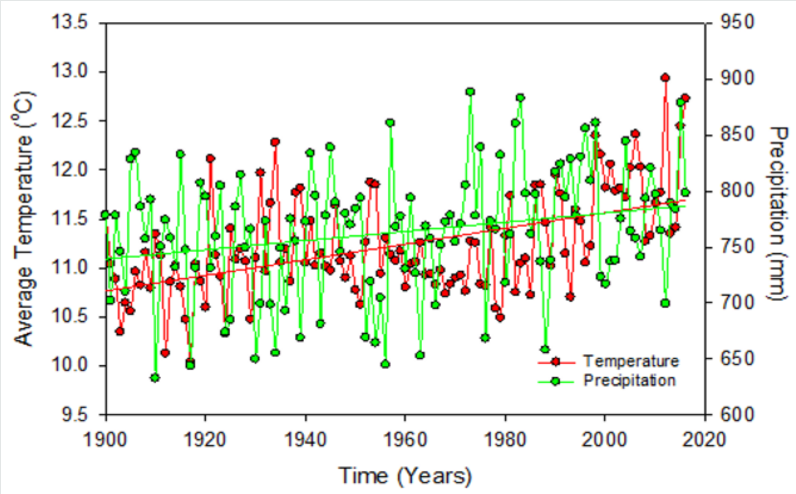

Figure 1: Mean Annual US Temperature and Precipitation, with Their Long-Term Trends (NOAA).

I. Crop type, cultivar selection, crop rotation, early planting, tillage operations, residue management, nutrient and pest management, and irrigation and drainage;

II. Composition and dominant tree and other vegetation species; and

III. Biodiversity, managed ecosystem distribution, and agricultural production.

Much land-use change research has been conducted based on predictive models in a spatially-explicit, multi-scale, and integrated manner, which is important for the quantitative exploration of alternative pathways into the future Anadon et al. [25]; Hughes et al. [26]; Lin et al. [27]. Common processed-based models that can fulfil above goals include Cropping Systems Simulation Model (Crop Syst), Soil and Water Assessment Tool (SWAT), Spatially Referenced Regressions on Watershed Attributes (SPARROW), Water Erosion Prediction Project (WEPP), Forest Hydrology Model (For Hy M), and De Nitrification-De Composition (DNDC). Many of these models have been tested at multiple spatial and temporal scales Arnold et al. [28]; Keum and Kaluarachchi, [29]; Shrestha et al. [30]; Tonitto et al. [31]. Integrated Valuation of Environmental Services and Tradeoffs (InVEST) is commonly used for social and economic evaluation, which defines how changes in an ecosystem's structure and function are likely to affect the flows and values of the ecosystem services across a landscape based on the production function Redhead et al. [32,33]. Effective land-use changes enhance ecosystem's resilience with respect to climate change by complex interactions among society, economy, and the environment. Land-use changes shift the dynamic balance of bio-physical and biogeochemical processes of managed ecosystems, which feeds back to the environment (e.g., through GHG emission and carbon sequestration), society (such as land use viability, public policies and regulations, and social institutions), and economy (e.g., financial profitability and local economic development). As such, environmental sustainability, social and political concerns, and economic policies must be aligned in order to increase the robustness of the ecosystem and mitigate adverse impacts of climate change.

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