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Land Use Capability and the Sustainable Scale: An Overview of Agriculture in São Paulo State, Brazil

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Abstract

Establishing a sustainable scale in natural resources management enables effective economic and ecological policies and guarantees the long-term sustainability of economic production. In agriculture, land evaluations determine the land use sustainable scales, that is, those that avoid land degradation and allow the provision of food, wood, energy, and ecosystem services over time. The paper assessed São Paulo State's agricultural sustainability by analyzing the current land use adequacy to the land use capability map that follows FAO 1976 "guide for land evaluation" and was applied to São Paulo by the State Agricultural Secretariat. Results indicate inefficiencies in land use at the state level, where more than one-third of agricultural lands do not satisfy technical land capability indications. According to technical land use capability, more than 4.5 million hectares are being underused (economic inefficiency) and another 2.2 million hectares are being overused (environmental inefficiency). Pasturelands represent the most unsustainable land use, where 3.7 million hectares are allocated in high quality lands with high agricultural production potential, and another 0.7 million hectares are allocated in lands with very low quality for agriculture, most of than area degraded. To achieve sustainability, lands with high agricultural production potential should be used to improve agriculture and food production and, on the other hand, lands with very low agricultural production potential should be used for wood production, agroforestry, ecotourism and natural ecosystems conservation. Our results provide a framework for improving land use policies in São Paulo State and highlight an opportunity to achieve land use sustainability.

Keywords

Land Use Planning, Land Capability, Agricultural Sustainability

1. Introduction

Decisions about land use are often based on private economic strategies and are not necessarily in line with society's wishes [1]. Nevertheless, the environmental and economic impacts that result from land use and land degradation affect the wellbeing and the quality of life of others, sustainable land use planning becomes necessary [2]. Land degradation is understood as the loss of environmental and productive capacity of land and results from inadequate land use and management [3]. It has consequences for farmers (*i.e.*, loss of productivity and lower income) and for society (*i.e.*, loss of ecosystem services and biodiversity). Research indicates that the cost of reversing land degradation, when recovery is still possible, is more than two to five times that required for sustainable use through conservation [4]. However, investments in planning and sustainable land use are still low priorities for most of countries. Agronomic techniques for land conservation are widely known by policymakers, however, most of policies aimed for land conservation are not aligned with a broader push program for sustainable land use and they usually becoming generally one-off policies with a local focus. The lack of land use planning policies is explained because of the diffuse nature of the impacts resulting from land degradation and, as a consequence, the low perception of the problem by the agents directly involved in the resource use and management or by other social stakeholders [3] [5].

Regional planning for sustainable land use complements the agronomic techniques of conservation and local soil management. It enables strategic land allocation for food production and also enables natural ecosystems conservation in low food production quality lands, ensuring the provision of essential ecosystem services [2]. The systematic evaluation of land's productive potential is an integral part of sustainable land use planning [6] [7] in that it indicates the uses that best meet the "sustainable scale" of land use. That is, they can reconcile better economic yields with the long-term conservation of land quality [8] [9] [10] [11]. São Paulo State, Brazil, has modern agriculture that accounts for one-third of all income generated by Brazilian agricultural production [12]. With an area of more than 24.6 million hectares (Mha), 73% is used for agriculture [13] [14]. Historically, the strength of São Paulo agribusiness was supported by the intense exploitation of its land, biodiversity, natural resources and environmental services. Decades of native vegetation substitution by agriculture resulted in degradation of two of the most important regional ecosystems, the Atlantic Forest and the Cerrado, both biodiversity hotspots [15]. The Atlantic Forest, which originally occupied 20 Mha has been reduced to 11% - 13% of its original cover [16] and its remnants are highly fragmented, dispersed, and degraded [17]. Likewise,

more than 90% of native Cerrado vegetation is degraded [18]. A direct consequence of this change in vegetation cover is an estimated soil loss due to water erosion of 30 tons of fertile soils every year in Sao Paulo [19]. Researchers estimate that, depending on soil characteristics, types of vegetation cover and land management, fertile soil loss from water erosion can reach 200 tons every year in the region due to inadequate land use and management [20].

The paper assesses the sustainability of São Paulo State agriculture through technical evaluation of the adequacy current land use to the land use capability and discusses opportunities to encourage agricultural sustainable policies in the state. The definition of a sustainable scale in natural resource use is one of the fundamental sustainability principles: the resource use rate cannot exceed its yield capacity [21] [22]. In agriculture, the capacity of land yield can be determined by assessing its use capability. In this sense, agricultural production is directly associated with the adequacy of land use concerning its use capability. In São Paulo State, Decree 41.719/1997 regulates agricultural land use and conservation and establishes land use planning foundations. This legislation determines that state actions and policies to plan land use should be based on technical evaluations of the land use capability established by the State Department of Agriculture [23].

2. Material and Method

2.1. Study Area

The study area corresponds to the limits of São Paulo State (**Figure 1**), located between 23.5432˚S, 46.6292˚W, and has an area of approximately 24.6 Mha. Agriculture occupies 73% of the land while the remnants of natural ecosystems occupy 18% of the land. The remaining surface area is occupied by road infrastructure, cities, water bodies and water reservoirs. In agricultural lands, the main uses are sugarcane (6 Mha), pastures (5.5 Mha), forestry (1.3 Mha), citrus (0.74 Mha), maize (0.7 Mha), soybeans (0.4 Mha), coffee (0.23 Mha) and another 3.3 Mha of land with a diversity of small crops [13].

2.2. Land Use and Occupation

The 2017 land use and occupation map [14] was used to identify eight land use classes: two for natural ecosystems (forest and non-forest), one for urban, and five agricultural uses (sugarcane, pastures, forestry, soybeans and "Other Anthropogenic Land Use"). The class "Other Anthropogenic Land Use" comprised a diversity of existing small crops (**Figure 2**).

2.3. Land Use Capability

Land use capability map of the São Paulo State, prepared by the Department of Agriculture and Supply [27] was used to achieve land use capability. This mapping represents a total area of 22.8 Mha and excludes urban areas, infrastructure, and water. Several methodologies exist to achieve technical land evaluation and

land use capability [11] [28] and those most used in Brazil are "Land Use Capability" [9] and "Agricultural Land Suitability" [29]. Land use capability assessment liens on interpretative classifications to evaluate its environmental and productive support capacities. The methodology divides land into three groups according to their physical, environmental, ecological, and topographic attributes. Group I land possesses a high capacity to sustain agriculture. Group II land is indicated for low intensive uses like pastures and/or forestry. Group III land has very low capacity to support intensive agriculture without degradation but is highly capable of conserving biodiversity and natural ecosystems. Capability assessments also weigh regional environmental limitations, ranging from land with few soil conservation problems to agricultural areas with serious issues. Group I lands are thus subcategorized into classes I, II, III and IV. Class I land has little or no soil conservation problem, whilst class IV areas face serious soil degradation when used for intensive agriculture. Lands belonging to Group II (classes V, VI and VII) are indicated for pastures and forestry. The environmental limitations in these areas preclude sustainable agriculture, as investments for soil conservation tend to be higher than the land expected economic returns. Group III, Class VIII, lands are greatly limited vis-à-vis agriculture and are best allocated to ecosystem/biodiversity conservation, ecotourism, recreation and water storage [9] (**Figure 3**).

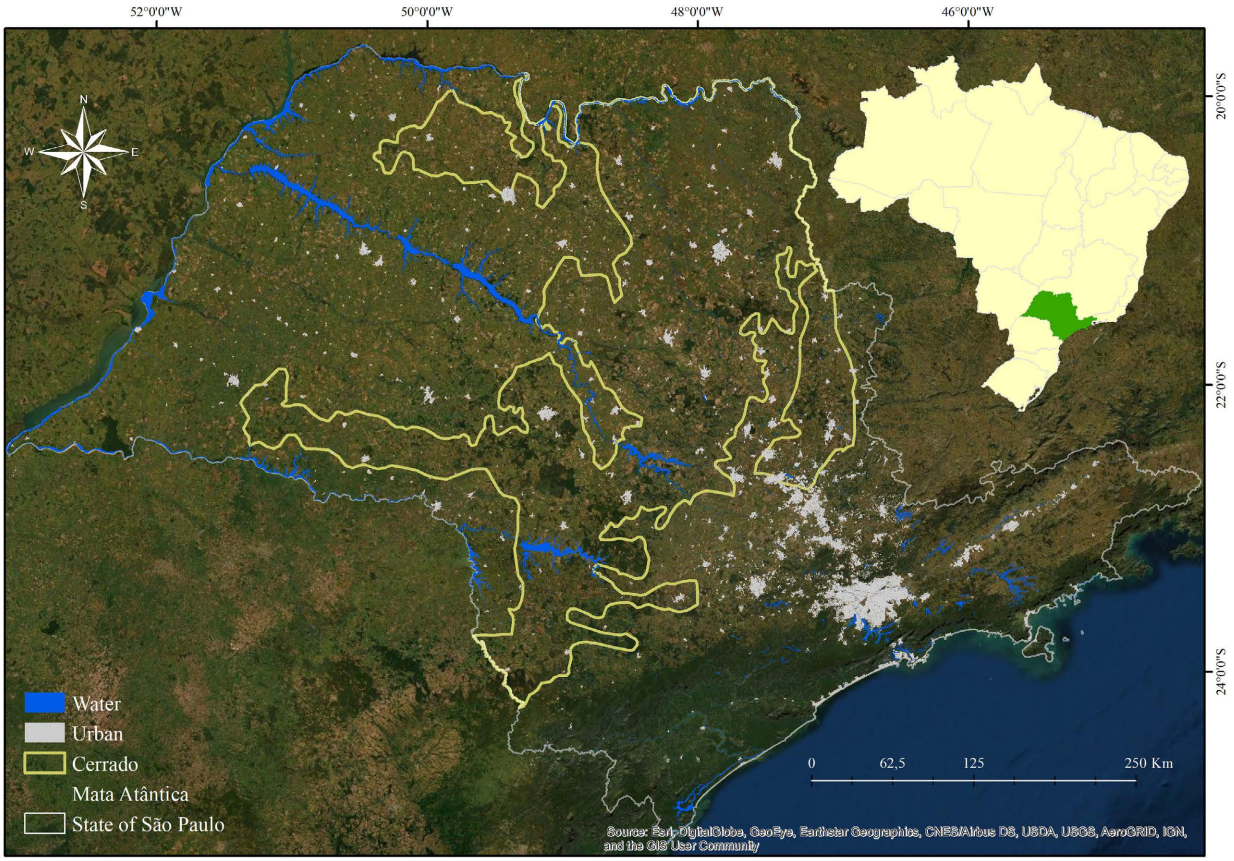

Figure 1. São Paulo State: cities, water, political limits and biomes. Source: [24] [25] [26].

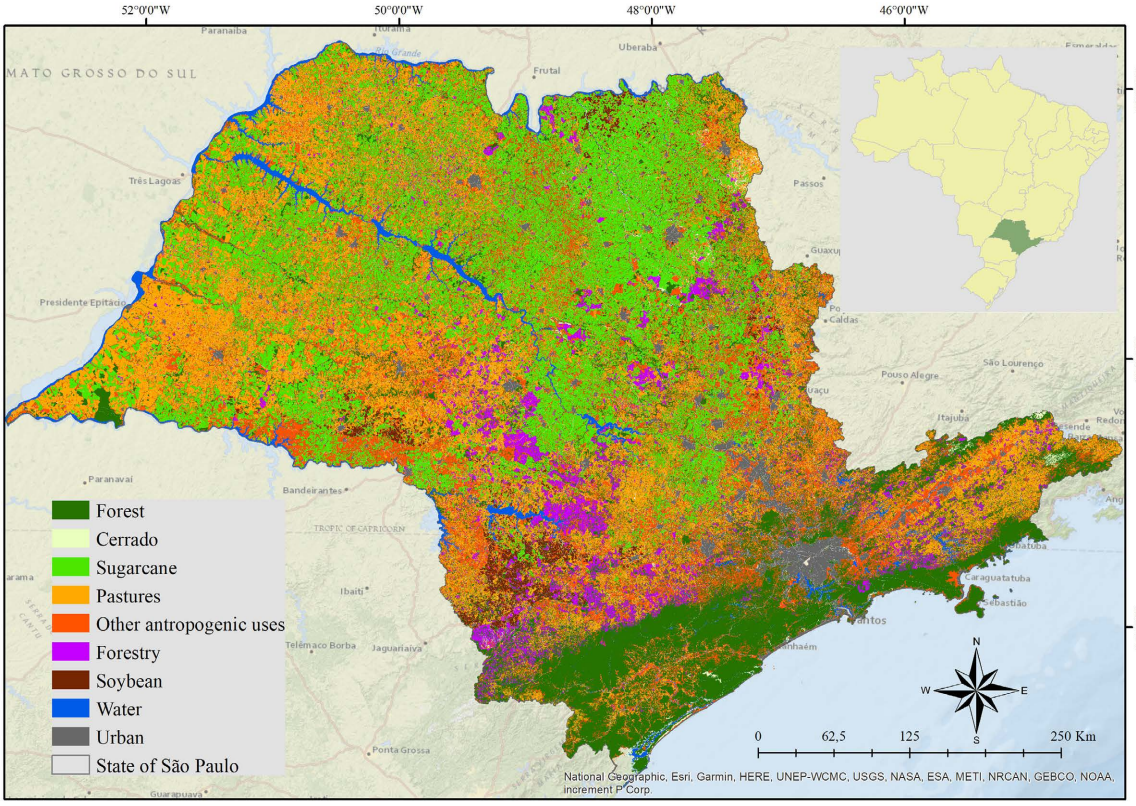

Figure 2. São Paulo State land use. Source: [14] [25] [26].

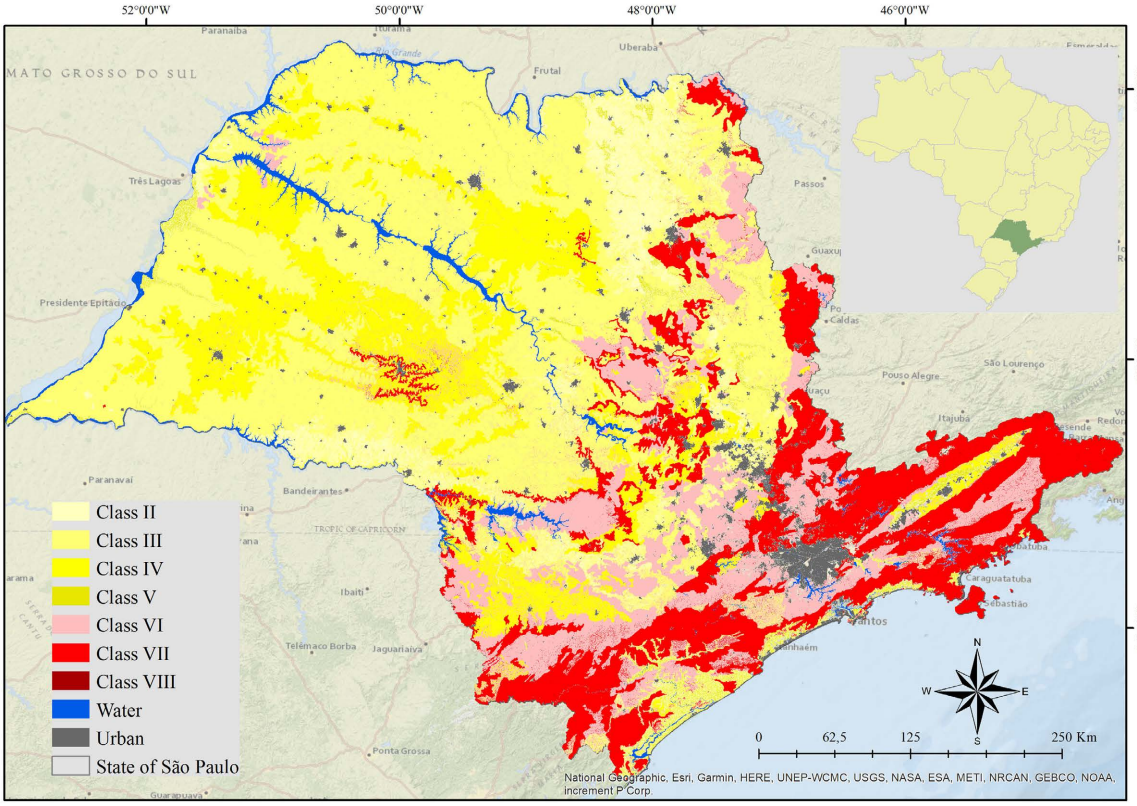

Figure 3. São Paulo State land use capability. Source: [25] [26] [27].

2.4. Assessing the Adequacy of Current Land Use and Potential Use Capability

To determine the current land use adequacy to its use capability in São Paulo State, the land use capability map [27] was intersected with the current land use map [14] using ArcGIS 10.4 software. The resulting table categorizes land based by the adequacy of existing land use and the land use capability. A basic rule for this cross referencing was considered the overlap between the potential for adequate use (indicated by the use capability classes) and the current verified land uses [30]. According to the methodology, appropriate use is those where the current use is compatible with technical indication. Similarly, inappropriate use is those where current use is incompatible with the technical recommendation. Inadequate use was subdivided into overused land and underused land. Overused land is those where the current use is higher than land use capability. In these cases, there is an increased risk of agro-environmental degradation in the medium and long term. On the other hand, underused land is those where current use is lower intensive than land use capability and its agricultural potential production. Here, there is economic inefficiency [30]. Natural ecosystems class was not analyzed according to land use capability. Like-wise, urban areas, infrastructure and water bodies were removed from the analysis because they represent irreversible uses.

3. Results

Sugarcane and pastures represents more than 60% of the agricultural land use in São Paulo State, comprising more than 11 Mha. While 87% of sugarcane occupation is adequate to its land use capability (classes II, III and IV), only 29% pastureland (5.5 Mha) is thecnically adequate to its land use capability (classes V, VI and VII). More than 3.9 Mha of high-quality land are currently used for pasture and are, therefore, underutilized. **Table 1** presents results from land use capability technical analysis for São Paulo State current agricultural land use:

Table 1. Land capacity classes, land use classes, and adequacy of current land use in São Paulo State. *Source*: [14] [27].

Land use capability	Land use classes						Total	Sustainable use	Technical analysis	
	Anthropogenic uses	Sugar cane	Natural ecosystems	Pastureland	Forestry	Soil			*underused*	*overused*
	Thousand hectares									
Class II	369	731	218	130	28	76	1.553	1.176	158	-
Class III	2.261	3.565	947	2.376	401	142	9.692	5.968	2.778	-
Class IV	1.003	958	339	1.409	169	109	3.988	2.071	1.578	-
Class V	89	38	105	37	5	2	276	42	-	130
Class VI	831	264	1.139	813	352	23	3.422	1.165	-	1.118
Class VII	737	216	2.000	753	172	10	3.888	925	-	963
Class VIII	0.817	0.001	7	0.124	0.017	-	7	7	-	0.8
Total	5.291	5.771	4.755	5.517	1.129	363	22.826	11.353	4.514	2.211

4. Discussion

The current land use for more than 6.7 Mha of agricultural land in São Paulo State is not technically appropriate to its land use capability. This represents 36% of the total state agricultural area and indicates low economic and environmental efficiency in the resource use. Pasturelands stand out as the main inefficient use category and could be the key to promote agricultural land use sustainability in the State. Pastures in high quality lands (70%) provides food, energy and economic returns below its natural potential (economic inefficiency) and can be easily replaced by high productivity crops since landowners are encourage to do that. On the other hand, pastures located on low quality lands have drawn the attention from a number of researchers as [31] [32] [33] [34] [35]. Those researchers indicate that changing land use in low agricultural quality land from pasture to forest is a promising way to scale up gains in the ecological restoration of natural ecosystems in several Brazilian states. They argue that low quality agricultural lands degrade rapidly when overused and compromises that land capacity for long term food and environmental services provisioning. Further attention should be given to remnant natural ecosystems. These currently occupy about 4.7 Mha (**Table 1**) and are distributed among all land use capabilities, with classes VI and VII being those containing the most native vegetation. It is important to highlight that Brazil's "Native Vegetation Protection Law" [36] mandates that São Paulo landowners conserve an area equivalent to, at least, 20% of their property with native vegetation. Thus, regardless of class, native vegetation remnants must be considered according to the legislation. Classes with high use capability (II, III and IV) possess 1.5 Mha of native vegetation, whilst those with more limited use (V, VI and VII) comprise 3.2 Mha. Class VIII areas, considered unfit for agricultural use, represent approximately 7500 hectares, of which remnants of native vegetation currently occupy 6400 hectares.

5. Conclusion

Considering the social cost of land degradation, results showed sustainable land use planning should be used to promote agricultural policies that redirect the current agricultural land use to a long term sustainable scenario. Although São Paulo State is a leading agricultural region in Brazil, almost 30% of this activity is outside the sustainable land use capability range of land use and extensive pasturelands are the main unsustainable land use. According to the land use capability technical orientation, high quality lands must to be used for high productivity food production, generating income and food security without land degradation. On the other hand, low agricultural quality lands, those who quickly degrade under extensive management, must be used for forestry, agroforestry, ecotourism, native vegetation protection and ecosystem services conservation. This land use sustainability scenario could be achieved through pasture productivity intensification incentives and setting aside low quality lands for silviculture, agroforestry, ecotourism and forest conservation.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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