Agriculture in Marginal Lands

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The term ‘marginal’ was originally used under the umbrella of economic theorizing to describe an area under given conditions where cost-effective production is not remunerated. Since then, different definitions describing the concept of marginality and marginal environments have emerged, highlighting the complex nature of marginality and how various unfavorable conditions disadvantage individuals and communities living in these areas. In the context of the agricultural economy, the term “margins of cultivation” is used to describe economically marginal agricultural lands where revenue from optimal production just equals (or is lower than, in some instances) the costs of production, leading to zero (negative) profit or economic loss. To capture this specific economic context, FAO and UNEP have classified land supporting a yield of only up to 40 percent of its productivity potential as marginal. Marginal lands are also identified as areas where “cost-effective production is not possible under given conditions, cultivation techniques, agriculture policies, and macro-economic and legal settings”. In this context, economically marginal land can be thought of as land that would not be cultivated at current output and input prices without the availability of government support programs. Marginal lands are mostly abandoned, as they are disadvantaged due to factors such as changing commodity markets, international competition, or the demographics of land owners and farm operators.

Keywords: Sustainable Production ; Agricultural Marginality ; Marginal Lands ; Research Engagement ; Policy Outlook

1. Marginality in the Context of Agriculture

The concept and definition of marginal land varies according to the aim for which the term is used and the given contextual background against which it is operationally applied [1]. Understanding the combination of agroclimatic potential and socio-economic setting provides a working definition of areas that are favored or less-favored for an agricultural purpose, at least for market-oriented production [2]. Less-favored agricultural lands refer to lands that are susceptible to low productivity and resource degradation because their agricultural potential is constrained biophysically by terrain, poor soil quality, salinity, or limited rainfall. The socio-economic dimension of marginality involves several aspects, including lack of access to markets and infrastructure, which cause expected economic and social wellbeing to lag behind.

Less-favored agricultural areas (LFAAs) include all less-favored agricultural lands plus any favorable agricultural land (e.g., not constrained by biophysical factors) that is remote or in rural areas with limited access to infrastructure and markets [3]. In other words, LFAAs include agricultural lands that are constrained by limited access to rural agricultural and market infrastructures, even though they might not be constrained by biophysical factors. Although multiple interlinked factors drive marginality, biophysical and socio-economic aspects are the two central dimensions in the context of agriculture, driving agricultural policy and economic welfare. Accordingly, in this paper we argue that LFAAs indicated by the shaded boxes (A, B, C) in **Figure 1** could be equated to agriculturally marginal areas. The definition of agricultural marginality is summarized in the paragraph in the following.

Sources/factors contributing to marginality		Socio-economic dimension (i.e., access to infrastructure and markets, public service, etc.)	
		No/limited access	Improved access
Agricultural potential based on biophysical and environmental factors	Low	**A.** Less-favored fragile and remote areas: water-scarce, steep slope, poor and degraded soils	**B.** Less-favored agricultural area: areas in arid and semi-arid regions
	High	**C.** Less-favored agricultural areas: remote areas with high degree of plant biodiversity, rich biotic environment	**D.** Favorable agricultural area

Figure 1. Characterization of agricultural areas based on biophysical and socioeconomic dimensions of marginality. Source: Adopted and modified from [3][4].

In light of the discussion above, agriculturally marginal areas refer to the less-favorable agricultural areas (LFAAs) characterized by resource degradation, constrained agriculture potential, and low productivity of agricultural resources attributable to biophysical constraints such as rugged terrain, extreme weather conditions, poor soil quality, salinization, drought and erratic rainfall, and other factors that present significant constraints for intensive agriculture. Marginal areas also encompass all LFAAs and any favorable agricultural areas (e.g., areas not constrained by biophysical factors) with limited access to rural infrastructure and agricultural markets where cost-effective production is likely unfeasible (without additional support) under given conditions, cultivation techniques, and policy or macro-economic settings.

2. Geographical and Regional Identification of Marginal Lands

The literature offers different statistics on the extent and prevalence of marginal areas, as different studies employ different methods, assumptions, and criteria to estimate the extent of global marginal lands. Marginal lands account for about 36 percent of global agricultural land (1.3 billion ha), and support roughly one-third of the world's population [5]. Worldwatch Institute [6] estimate that the extent of marginal lands ranges anywhere between 100 million and 1 billion hectares. The estimated global area of abandoned agriculture is 385–472 million hectares [7]. Among the first studies to determine the extent of marginal lands and the distribution of the rural poor on less-favored marginal lands globally was the comprehensive study carried out by the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR), covering 105 developing countries across four regions. According to the CGIAR/TAC report [8], "favored" agricultural lands accounted for only 10.7 percent of agricultural area in the developing world compared with 24% of marginal agricultural lands.

The Food and Agriculture Organization (FAO) of the United Nations, with the collaboration of The International Institute for Applied Systems Analysis (IIASA), developed a system that enables rational land-use planning on the basis of an inventory of land resources and an evaluation of the biophysical limitations and production potentials of land. This is referred to as the Agro-Ecological Zones (AEZ) methodology [9][10]. GAEZ modelling uses detailed agronomic-based information to simulate land resource availability, assess farm-level management options, and estimate crop production potentials. It employs detailed spatial, biophysical, and socio-economic datasets to distribute its computations at fine-gridded intervals over the entire globe [11][12]. The GAEZ methodology combines soil, terrain, and climate characteristics with crop production requirements, and estimates the suitability in terms of land extent and attainable yield levels. Crop production was assessed at each land grid cell at the 5-arc-minute level at four technology and management levels (low, intermediate, high, and mixed).

Based on the GAEZ suitability assessments, global land resources (excluding Antarctica) comprise 13.15 billion ha (**Table 1**), of which 46% is classified as not suitable for production (i.e., characterized by less than 5% attainable yield potential) and about a fifth of the total land or 21% (2.7 billion ha) is classified as marginal land, with various degrees of suitability for production, including marginally suitable and very marginally suitable, based on attainable yield potential. Out of the 1.6 billion hectares (ha) that are currently in agricultural use, about 225 million ha (nearly 15%) are classified as marginal.

Table 1. Availability and classification of global land resources.

	VS	S	MS	mS	vmS	NS	Total	Potential (VS + S + MS)	Potential (mS+ vmS)
Total land (in million ha)	1315	2187	993	1111	1627	6061	13,294	4495	2738
in %	10%	16%	7%	8%	12%	46%		34%	21%
In agricultural use (1999/2001)	442	616	201	120	104	75	1558	1260	224
of which rainfed	381	516	166	93	84	43	1283	1063	177
of which irrigated	61	100	35	27	20	32	275	197	47
Gross balance	873	1571	792	991	1523			3235	2514
Under forest	453	854	293	342	530	1263	3735	1601	872
Strictly protected	30	50	27	39	59	432	637	107	98
Built-up land	41	61	14	12	10	15	153	116	22
Net balance	349	606	458	598	924			1412	1522

3. Research and Development (R&D) and Policy Outlook

Global agriculture will seemingly face daunting challenges over the decades to come. On the one hand, there is a need to produce more food for a growing and increasingly wealthy population that demands a more diverse diet. On the other hand, in many developing countries with larger share of rural poor, agriculture must also play a dual role and contribute to economic growth, rural employment, and poverty alleviation. On top of this, agricultural systems will face increased competition for scarce natural resources, such as land and water, while helping to preserve biodiversity and restore fragile environments. Ultimately, these resource-poor farmers will have to play a crucial role in mitigating climate change shocks whilst also adapting to increased biophysical stresses including extreme weather events such as droughts, soil degradation and salinity, and heatwaves, all of which threaten global food security.

Despite the substantial drop in the incidence of poverty globally, 10% or 734 million people are still considered poor, subsisting below USD 1.90 a day. The progress in achieving the overarching goal of poverty reduction has been largely uneven. Most favored areas significantly benefited from the technological progress, but the rural poor, especially those in marginal areas, benefited the least and in some regions the number of poor has even increased. Most researchers agree that typology of poverty is explicitly linked to environment, with marginal areas representing the highest concentration of extreme poverty. Agriculture is strategically the backbone of the economies in these marginal areas, but the productivity of agriculture is undermined by several biophysical and socio-economic constraints, making marginal lands more fragile and difficult for policymakers to make successful investments in. Expected future gains in food productivity in marginal areas are important because it is unlikely that increased productivity in favorable environments will be sufficient to meet projected growth in food demand for the global population that is likely to reach 10 billion by 2050 [11][13][14], particularly with prevailing climate change and biodiversity loss.

Despite the challenges faced by the marginalized poor, marginality is a temporary and dynamic concept. Each region has the potential to overcome perceived marginality and the negative consequences of marginality can serve as the starting point of innovations and potential [15]. For instance, an area might be marginal, or less favored for use in crop production under a specific production system, due to water scarcity or lack of market access, but by introducing new water-saving technologies or new marketing routes, this same area could become more favorable [16] or transformed from unproductive (unused) to productive (used) land, or from sub-marginal to supra-marginal land along spatially-varying background conditions [1]. Any change in force governing peoples' willingness to use land will lead to a transition between "marginal lands" and "normal lands" [17].

Research Engagement and Priorities

Research and development (R&D) and investments in areas with high agricultural potential cannot be neglected because these areas still provide much of the food needed to keep prices low, and to feed growing livestock and urban populations [18]. However, with the predicted trends in the population, extended R&D and greater public investment in some low-potential areas could offer a win-win strategy for addressing productivity and poverty problems; thus, investments in R&D in marginal areas may actually give higher aggregate social returns to a nation than additional investments in high-potential and prime areas [4][19].

Proper economic analysis of policy options and their impacts on small-scale and marginal farmers in resource-poor regions requires collecting appropriate data, methodology, and analytical tools for the economic valuation of environmental impacts. On this front, future research insulation must focus on collecting comprehensive and in-depth information on agricultural and resource management practices in marginal areas. This will enable future policy makers to make informed decisions and design policy instruments to address long-term issues related to productivity, environmental degradation, technological issues, food security, and poverty. Given this diversity of agroclimatic conditions in marginal areas and the need to tailor R&D to local conditions to help define and identify marginality hotspots, poverty mapping as well as GIS techniques and spatially referenced data sets are proving useful in defining and mapping different types of less-favored areas at detailed scales in terms of the basic livelihood options available at community and household levels [20][21].

Investing in targeted R&D to focus on the crops and traits that are important to the poor and the particular environmental limitations they face can diminish marginality and contribute to a widespread reduction of poverty [22]. Intensive research with a concentration on the poor in marginal environments may require a renewed research focus on some of the neglected and under-utilized crop and livestock species, particularly those that have the highest potential value for farmers' subsistence as sources of nutrition and food security. Conventional research methods that have proven successful in productive, favored areas may not be directly applicable under lagging and marginal production environments; therefore, future research should improve the local adoptability of neglected species with emphasis on targeted methods that could respond to the particular conditions of such biophysically and environmentally constrained areas. Agricultural research for marginal areas will need to generate developmental opportunities for targeted crop species that are central to the livelihoods and food security of the poor, and develop crop varieties with improved nutritional properties and better performance under low inputs and biotic and abiotic stresses.

Successive research documented several crop species that could thrive in marginal environments. Recently, there has been rising interest in introducing bioenergy production in marginal lands [23][24], and food crops such as quinoa and other halophytes that exhibit high tolerance to abiotic stresses typical of harsh climates [25][26]. In fact, numerous empirical research studies have corroborated competitive economic returns on investments in parts of India and China [18]. Quinoa was declared as a strategic crop by the Food and Agriculture Organization (FAO) due to its recognition as a stress-resistant crop with high nutritional value which is especially important for food security in marginal areas. However, little is known to the public and policy makers about the adoptability of these crops and their nutritional value. Other crops, such as halophytes including *Salicornia*, types of millets, and some forage crops, can be successfully adopted to marginal areas especially in dry areas where lands are degraded by salinity. Hence, further attention should be given to R&D for marginal areas to focus on specialized breeding facilities to develop high-yielding, nutritious, and stress tolerant crop species for marginal conditions.

It is widely believed that the marginalized poor do not perceive that they benefit as much from environmental conservation efforts, while suffering the most from environmental degradation. The poor are often more vulnerable than others to the loss of ecosystem functions that restrict the availability of natural goods and the performance of services. This entails the direct dependence of the marginal poor upon ecosystem services. Thus the dynamic patterns of dependence on ecosystem services of the poor and their coping strategies require regionally specific and in-depth evaluation [27]. Soil degradation as the primary source of agricultural marginality poses a serious threat to diminishing soil functions and their ability to support ecosystem services essential for human well-being. In marginal areas, soil quality degradation has reportedly affected a significant amount of land and is expected to spread with climate change. Research and knowledge on soil quality management through soil amendment and customized fertilizer mixes are indispensable if we are intending to achieve the sustainable use and management of marginal lands. Marginal environments are mostly degraded because of unsustainable land uses; therefore, research to generate knowledge and information on sustainable land use, governance, and ecosystems must be prioritized.

Besides sustainable land management, water scarcity and quality remain major biophysical constraints that challenge sustainable production in marginal areas. To make informed decisions, policy makers need to know more about the type and the techniques of irrigation systems and practices that are best suited to marginal agricultural areas. In addition to water, water quality seems to be declining. Using treated water has become relatively common in agriculture; however, the research community will need to spend more on the quality as well as energy requirement for treated water. In areas where salinity is a major issue, leading to a low quality of soil and water, research must assess the economics of desalinization technologies and the appropriate crop intensification and rotation regimes under the context of biosaline agriculture.

Additional knowledge and research work are required to assess the suitability and viability of protected agriculture as a strategy to increase productivity per unit of land under marginal environmental conditions. Given the anticipated increase in population, per capita land is expected to decrease substantially, making land a binding and scarce resource. On this front, protected agriculture as a potential strategy to limit exposure to unfavorable biophysical stresses and extreme weather events can substantially increase yields, land productivity, and mitigate production risks. Moreover, protected agriculture technologies can ensure consumption smoothing over the year through off-season production, especially for subsistence smallholders who must subsist on their own production. Protected agriculture may also promote climate-smart and environmentally sustainable use of resources, as they are especially water-efficient.

Outlook for Future Policies

Sustaining agriculture and livelihoods in agriculturally marginal areas requires a significant shift in the current policy environment away from soothing short-term to more comprehensive policies that favor long-term viable investments to effectively respond to the growing food demand in the decades to come. The well-established link between poverty and environment [28] requires long-term food–poverty–environment-focused development policies to address deep-rooted poverty and create an enabling environment for the extreme poor to become part of mainstream economies, while restoring the natural resource base in the presence of growing threats posed by climate change. Future policies must evolve around a framework that is all-inclusive but context-specific. An integrated and holistic policy approach is necessary to advocate for collective action, engaging research institutions, policymakers, farmers and consumers, and other stakeholders to unlock the untapped potential of marginal lands. Deploying policy instruments targeting individual aspects of farming in isolation implies leaving too many “loose ends” and therefore is less likely to achieve the strategic developmental goals. Hence, an all-inclusive, integrated, and participatory policy approach is indispensable to engage all parties to align synergies and join forces in targeting productivity enhancement, whilst improving the fragile resource base in the face of severe climate change.

Ideally, geographical areas that are categorized as extremely marginal areas should be prioritized for future research and development, followed by other areas that are moderately marginal. Such areas will require immediate research and development support to effectively contribute to achieving SDG One and Two. Future policy interventions will vary in scope depending on the severity and type of factors leading to marginality within these hotspots; that is, context-specific approaches and R&D actions will need to be designed to target dimensions peculiar to the individual marginality hotspot. Recent developments in land use and agricultural policies show significant progress towards sustaining agriculture production in marginal agriculture [29].

Public investments to promote more sustainable development pathways are warranted in marginal areas on both poverty and environmental grounds. The design and scope of potential interventions largely and essentially depends on the dimension of marginality being targeted and the local or regional economic context. Strategic options may vary from encouraging additional out-migration, promoting income diversification into nonfarm activities, increasing recurrent expenditure on safety net programs, supporting more intensive pathways of agricultural development, and introducing payment schemes for environmental services. Although non-agricultural options are perhaps more economically viable in transforming and industrializing economies with dynamic non-agricultural sectors, they are less viable in poor agrarian communities with stagnant economies [20][30].

Future interventions aiming to target agriculture in marginal areas need to take into account the local comparative advantages and the heterogenous nature of marginal environments [31]. Strategies for less-favored areas are likely to be more effective if they are linked to the development pathways that have comparative advantages in particular circumstances. For instance, small-scale water-saving irrigation technologies are likely to yield the highest returns with suitable soil conditions, since these can enable intensified and high-value crop production. On the contrary, road development is likely to have the highest returns in densely populated areas with good agricultural potential but limited market access, by enabling the marketing of high-value commodities and inputs. Investments in education and training are vital in low-potential areas with limited market access where immigration is likely to be an important element of people's livelihood strategies for the foreseeable future [4].

Tradeoffs between economic growth and poverty reduction objectives are more likely to arise in public investment decisions. Thus, another dimension of potential future policies is finding the right balance between income-generating and supportive activities (i.e., food security) and land use (e.g., land use for farming vs. urbanization). Since poverty and food security goals are strongly interlinked with environmental goals, future policy interventions need to identify and address where tradeoffs arise to ensure resources in both prime and marginal areas are sustainably used in achieving SDGs. Policy attempts to address individual goals in isolation will not only fail to target the rural poor, but will also put pressure on the natural resource base and lead to further dependence on exploiting environmental resources.

From a technological standpoint, major breakthroughs in productivity-enhancing agricultural technologies will be essential to reverse resource degradation and put marginal lands into optimal use. The Green Revolution may actually have created new sources of food insecurity in marginal areas by targeting high-potential areas and a handful of high-value and input-intensive crops grown there, mainly wheat, rice, and maize [32][33][34]. Policies for marginal environments must encourage the use of ecological processes instead of relying entirely on external inputs for crop production. Technologies that help reduce risks (by increasing tolerance to drought, pests, or frost, for example) and conserve and improve resources may be more effective than those that simply promote high yields in response to high levels of inputs [4]. Future technologies should account for and must be suited to the high degree of diversity in biophysical and socioeconomic conditions typical of marginal areas. The scope of future technological innovations must be different in several ways, so to be able to directly target the remaining poor (i.e., they should be cost-effective, productive, and sustainable).

The process of innovation and technological development for marginal agricultural environments must be based on a synergy between researchers and the marginalized farmers as the end users. Resource-poor farmers should not only be passive recipients of improved technologies but must play an active part in developing and adapting technological solutions to meet their own particular circumstances [35]. The proposed strategies for technological development should therefore be participatory and demand-driven, stimulating and building upon farmer innovations that are fit to local circumstances.

The importance of land tenure programs is reflected in the Sustainable Development Goals. As land holding size is substantially low in most parts of Sub-Saharan Africa, South Asia, and other agriculturally marginal areas, and will continue to decrease due to land fragmentation and land-use planning, governance and tenure policies are becoming very critical. Insecure land tenure rights and weak governance drive more marginalized and vulnerable people into being evicted from their farms, with women farmers being particularly at risk. As a result, rural unemployment is likely on the rise. Tenure reforms generate positive welfare effects for resource poor farmers [36]. Improving secure access to land affects how people decide to use land resources and whether they invest in potential land improvement activities. More secure and equitable access to land can help empower disadvantaged groups (particularly women and marginalized populations) and ensure employment of the poor to their lands. Farm policies intended for marginal agriculture must therefore reinforce endogenous property rights systems to secure ownership rights over land and other resources.

Initiatives targeted at policy makers, researchers, and agribusinesses need to be aligned with capacity-development actions. They should seek to integrate knowledge generation with knowledge sharing in a manner that can effectively inform, and be informed by, action [37]. Farm households' decision-making in the context of risk and resilience challenges is often constrained by a lack of information on weather and market conditions. Many farmers in remotely marginal areas rely on an informal knowledge of local climates and weather patterns that has been acquired over decades or even centuries. The challenge posed for these households is that much of this knowledge base will be effectively destroyed as it is rendered irrelevant under the new climatology [38]. Policies for marginal areas should make efforts to encourage restoring knowledge base and risk-coping mechanisms including weather forecasts, early warning systems, extension systems, and drought monitoring and forecast models, especially for reaching disadvantaged and indigenous populations.

The impact of market reform policies in marginal areas has been mixed and often detrimental to the poor [31]. Since the development potential of marginal regions is often constrained by poor infrastructure and market access, the public sector must create an enabling and supportive policy environment to induce and incentivize investments in agricultural R&D, rural infrastructure, and market access, to aid in transforming local subsistence production into market-led commercial production systems. Farmers, especially the smallholders, are poorly endowed with productive assets and liquidity constraints limit their access to modern inputs. Government policies at the national level must therefore invest to remedy market distortions, enhance the functions of local markets, and ensure access to long-term and affordable credit.

Coordinated public and private investments in the agriculture and food sectors must be a key dimension in future policies for agricultural and livelihood development in marginal areas. Attracting long-term private sector involvement will not only increase investments but will also promote resilience and efficiency in agri-food systems. The private sector could play an increasing role in creating “shared value” as an innovative business approach in which the long-term value and allocation of investments is shared between society and shareholders [39]. This means any involvement by the private sector in making business decisions on future plans should recognize social value, to ensure the needs and participation of the marginalized poor are reflected in business models undertaken by private sectors. The Nestle’s dairy n India and Pakistan are a good example of creating such shared values, as they have invested to strengthen local dairy businesses, but also provided benefits to the wider society through infrastructure development and educational programs on production management, nutrition, and other aspects [39].

Given the increasing threat of climate change, the adaptation of climate-smart agricultural and regenerative agricultural practices must be placed on the top of the policy agenda for marginal areas to transform and reorient agricultural systems to effectively support development and ensure resilience against climate effects. Inter-disciplinary R&D efforts will need to increasingly recognize the need to understand resilience against climate change and the sustainability of low-carbon economies. Poverty is evidently linked to environments in the context of marginal areas leading to the unbreakable poverty–environment traps [28]. Policies for restoring marginal areas must not be only poverty-focused but must also involve recommended conservation practices. The adoption of resource conservation technologies like zero tillage, residue application, permaculture, an appropriate use of fertilizer mixes, salt-tolerant varieties of crop, and promoting bio-saline agriculture practices will further enhance the potential of marginal lands to sequester carbon. In addition, the reclamation and improved management of degraded and salt-affected lands present great opportunity in marginal areas where salinity already happens to be affecting a large share of lands and will continue to spread at an increasing rate. Policy actions aimed at promoting resilience against climate change must address cross-cutting issues in all sectors. Tackling only the causes and impacts of environmental stresses facing agriculture production is a fragmented action that provides a partial solution only in the short run. In managing climate change, it is important to avoid considering its impacts in isolation from other processes of change, such as urbanization, land use, agricultural production, water resource management, and the use of other natural resources.

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