Challenges and Opportunities for the Adoption of Integrated Farming Systems: Lessons from Brazil and Beyond

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Abstract: Brazil's rural landscapes are critically important for global climate, economic development, and food security. The integration of crop and animal production within a single farm (ICLS) is a promising agricultural innovation to improve livelihood and environmental outcomes in these landscapes. Here we synthesize recent work examining the drivers of ICLS adoption in Brazil, as well as the economic, environmental and social tradeoffs associated with these systems, with a focus on the Legal Amazon region. Our research finds that ICLS are largely an economic and environmental win-win compared to existing extensive cattle management practices and other pasture intensification alternatives. Adopters of ICLS are well aware of the economic benefits of these systems – improved income, greater adaptability, and reduced environmental impact, while non-adopters are less aware of the benefits. High upfront costs, greater managerial intensity, existing lifestyle preferences, as well as limited access to markets, credit, and technical information remain key barriers to diffusion. Given these diverse barriers to adoption, a comprehensive mix of positive and negative financial incentives is needed to both push and pull further intensification innovations from their current niche to widespread adoption. On the push side, there is a need to vastly increase the number of demonstration farms and training seminars on successful ICLS practices. On the pull side, agricultural policies need to be re-oriented to accommodate the longer-term benefits of ICLS, including longer payback periods on loans and positive incentives for intensification via stringent restrictions on deforestation for additional land clearing and payments for environmental services. Finally, joint efforts by the private sector and government are needed to promote cattle value chain upgrading, including improved infrastructure and machinery access to enable pasture renovation

and crop production in more remote regions, and better transparency about cattle origin and management practices to signal the sustainability of the sector.

Introduction

Brazil is one of the largest global producers of food commodities, including beef, milk, corn, oranges, soy, and sugarcane. Yet a majority of the country's agricultural area is degraded, low productivity pasture (IBGE 2017). Amidst rapidly growing global demand for these commodities, intensification and recuperation of the country's existing pastures could hold the key to protecting the country's remaining tropical forests and savannas (Strassburg et al. 2014), which are among the largest in the world. Given the low levels of economic development in the Amazon and Cerrado, innovations in agriculture that increase the farm incomes may also be an essential pathway for sustainable development in the region (Garrett and Rausch 2015; Medina et al. 2015).

The Amazon and Cerrado biomes in particular face the monumental challenge of reconciling conservation with agricultural growth and development via sustainable intensification of existing areas. Despite many technological advances and rapidly advancing supply chain infrastructure, such intensification remains a challenge. Integrated crop and livestock systems (ICLS), which couple crops and livestock production through in situ animal grazing, hold formidable promise to meet the needs of farmers to produce high levels of food and farm revenue and reduce risks to climate change and market fluctuations, while also reducing agriculture's water and climate footprints (Schiere, Ibrahim, and Van Keulen 2002; Garrett, Niles, Gil, Gaudin, et al. 2017). Yet, adoption of ICLS in the Amazon and Cerrado remains low (Vicente 2016). Here we synthesize recent work examining the drivers of ICLS adoption in Brazil, as well as the economic, environmental and social tradeoffs associated with these systems, with a focus on the Legal Brazilian Amazon.

Integrated systems are largely a win-win option from an economic, climate, and environmental perspective

A bio-economic whole-farm model using data from Mato Grosso, a state that spans the Brazilian Amazon and Cerrado, found that ICLS can produce nearly three times more income and seven times more protein relative to extensive,

continuously grazed beef cattle systems, with fewer greenhouse (Gil et al. 2018) (Figure 1). The integrated system could also produce more income and protein than a rotational grazing system, with fewer greenhouse gas emissions. ICLS also performs better than extensive grazing and rotational grazing under pessimistic (i.e., RCP 8.5) and optimistic (i.e., RCP 2.5) scenarios of climate change. ICLS also perform better than extensive grazing in terms of energy and water usage per unit of protein produced. Integrated systems are even more profitable than continuous soy production when ranchers operate at the economically optimal number of cattle per hectare (estimated as 5.8 animal units for the model farm).

Though ICLS has a higher upfront investment than either continuous cropping or traditional grazing systems, an economic viability study based on seven years of experimental data in Mato Grosso showed that ICLS has a shorter payback period (4 years) than continuous soy and corn production (6 years) and continuous pasture (5 years) (Reis et al. 2019). Furthermore, the net present value and internal rate of return, and return on investment are all higher than continuous cropping and extensive grazing.

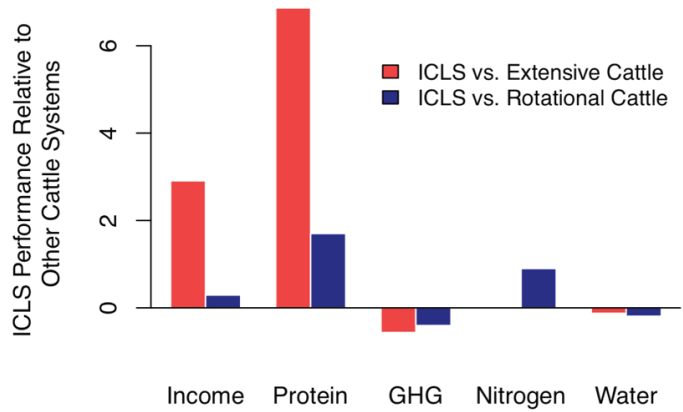

Figure 1. Economic and environmental performance of an integrated crop and livestock system relative to extensive or rotation cattle grazing on a model 2000 hectare farm in Mato Grosso. The ICLS farm produced US$ 638/ha and 299 kg human digestible protein (HDP)/ha with a stocking rate of 5.8 animal units/ha. The environmental impact per kg HDP was: 39 kg of carbon dioxide equivalent, 0.38 kg, Nitrogen, and 300 kg of water.

Many farmers are already aware of the potential benefits of integrated systems, but both existing adopters and non-adopters cite several pressing challenges to adoption

The Brazilian Amazon and Cerrado contain both frontier and developed agribusiness contexts, which span low input, sprawling cattle ranching, to small-scale fruit and horticulture farming, to intensive soy and corn production. Interviews with farm operators and local experts in Acre, Rondônia, Pará, and Mato Grosso from 2014-2018 (Cortner et al. 2019), found that there is nearly universal agreement among integrated system adopters that these systems help to:

a) Increase the competitiveness of cattle ranching, particularly in light of decreasing land availability and growth of the crop sector;

b) Increase cattle productivity, especially where pastures are highly degraded;

c) Increase farm income by adding value to both crop and livestock operations and diversifying revenue streams; and

d) Increase farmer adaptability and reduce risk to market and weather variability.

However, farmers cited numerous drawbacks and barriers to adoption (Figure 2). In regions that are farther from existing consolidated soy and corn production areas, there is an absence of silos to store grains and multinational traders to create competitive market access conditions. Poor road quality increases the costs associated with accessing these resources. Farmers reported that it was difficult to find or train skilled labor to work in integrated systems. Many also cited an inability to access credit to cover the costs and risks of establishing an integrated system. For example, in Mato Grosso, establishing an integrated farm can cost $863/ha vs. $174/ha for conventional ranching (Reis et al. 2019). Low credit access is exacerbated by land title documentation challenges, particularly in Pará.

Finally, ranchers expressed an aversion to taking on debt or taking risks given the uncertainty about returns, as well as little desire to take on greater managerial intensity as other reasons for not adopting. Technical experts and farmers alike

linked these preferences to a high cultural value placed on well-being, rooted in safety, tranquility, and relationships (segurança), which may dampen the perceived benefits of ICLS despite the promise of higher financial returns. Our research also indicates that increases in protected areas and enhanced enforcement of compliance with forest regulations are creating the perception of increased land scarcity and rising land prices, motivating farmers to find ways to add value to their existing land. Indeed, the relationship between increasing policy stringency and intensification has been identified throughout the Brazilian Amazon (Koch et al. 2017; Garrett et al. 2018). But farmers still believe that they should be rewarded for the climate mitigation benefits that their sustainable intensification efforts are providing by receiving a payment for environmental services.

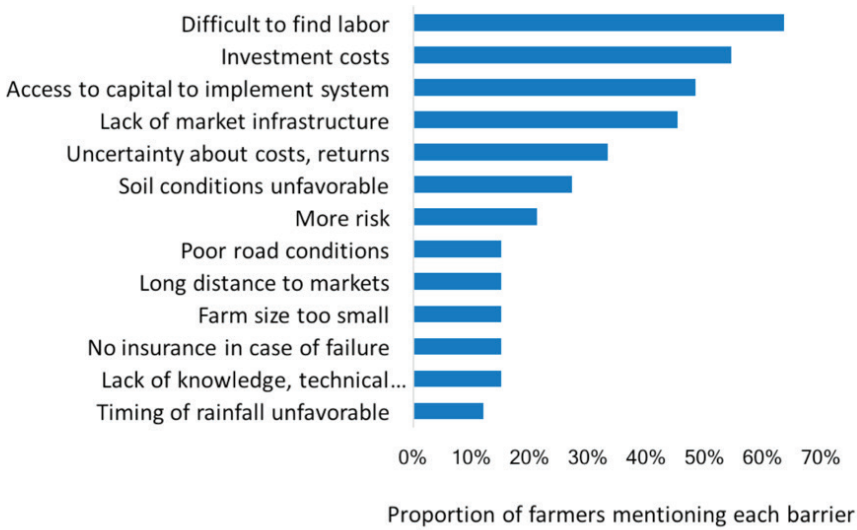

Figure 2. Perceived barriers to adopting integrated crop and livestock systems (number of respondents = 33).

Higher education and access to technical information and relevant supply chain infrastructure are key enabling factors for diffusion at the regional level

Spatial analysis of adoption patterns at the state level in Mato Grosso has shown that adopters of integrated systems are more educated and have better access to technical assistance and sector information than continuous crop

farmers or ranchers (Gil, Garrett, and Berger 2016). This analysis also found that farmers located in close proximity Embrapa research and demonstration units had significantly higher adoption of these systems.

Policy implications

A multi-level analysis of the socio-technical and policy landscape and existing agricultural regime in Brazil and other major cattle production countries indicates that a comprehensive mix of positive and negative financial incentives will be needed to motivate ranchers to increase integrated system adoption (Garrett, Niles, Gil, Dy, et al. 2017; Garrett et al. In Review)(Table 1, Figure 3).

Table 1. Challenges for the scalability of ICLS and policy needs.

Challenges for scalability	Policy needs		
High upfront costs and difficulty accessing loans	Regularize land tenure and make loans for entire production system, not just individual crops	Provide insurance for investment loans	Increase payback period and reduce interest rate of loans
Lack of access to technical information and labor force with required skills	Increase ICLS demonstration farms	Increase rural training programs	Involve farmers in design of future ICLS experiments
Supply chain inadequacies	Increase access to public machinery and silos	Improve supply chain infrastructure to increase access to crop markets	Upgrade value chains to provide ranchers with premiums for sustainable production
Lack of positive incentives to change practices	Provide positive incentives via payments for ecosystem services		

In order to improve adoption of integrated systems, agricultural research programs should be redesigned using participatory approaches to focus more on whole farm outcomes. The federal and state governments should allocate more resources towards training and capacity building among agricultural technicians and extension personnel. Additional field experiments should be es-

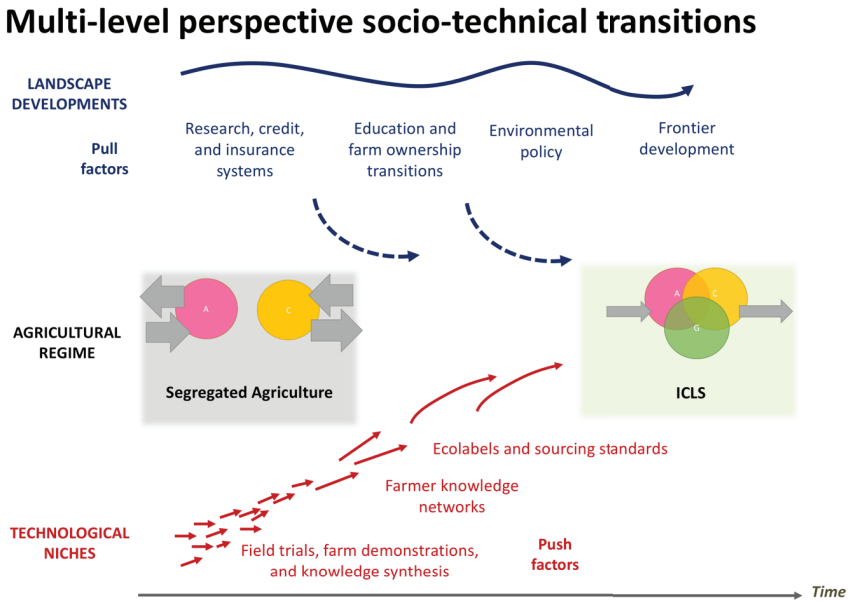

Figure 3. Multi-level perspective on push and pull factors needed to move ICLS from a niche innovation to mainstream practice. Adapted from Garrett, Ryschawy, in Review.

tablished in the regions that are best primed for adoption and most in need – predominantly cattle ranching communities, located near slaughterhouses but close to consolidated crop areas where cropping supply chain infrastructure is also available. Agricultural research organizations should increase gatherings, organization and knowledge exchange on successful farms that have already adopted ICLS and work jointly with farmers to develop and disseminate successful forms of ICLS, for example via demonstration plots and field days. Access to information about outcomes from experiments and outcomes on the farms of early adopters could be greatly improved through social media, such as the integrated crop and livestock YouTube channel, to increase exposure to the technology. Agricultural researchers and practitioners should foster knowledge exchange regarding ICLS between farmers and other cross sectoral stakeholders. Cooperatives could play a role as change agents in the organization of local exchanges among farmers and broader diversification of products by identifying new markets.

The government already offers low interest loans for integrated system investments through the Low Carbon Agriculture Program. Yet uptake of this credit is somewhat limited and did not explain differences in ICLS adoption across regions. In order to promote wider adoption of ICLS, credit systems should be adjusted to take into account a longer-term view of improved whole farm outcomes from system transformation, including a reduction of economic risk and negative social externalities relative to private returns.

Brazilian beef cattle value chains must be upgraded to access markets that provide premiums for socially and environmentally responsible products. Research and marketing organizations should work together to brand beef production produced with integrated systems for these higher value markets. Labeling programs and certifications could help with this effort. Additionally, the government could help incentivize more sustainable management by providing a system of payments for environmental services associated with changes in farming practices.

Conclusion

Given the magnitudes of Brazil's grain and beef sectors and remaining forest area, sustainable development of the Brazilian countryside will have large repercussions for global climate and food security. ICLS offer the opportunity to reconcile conservation and agricultural growth in the Brazilian Amazon and Cerrado to meet these sustainable development challenges. ICLS are largely an economic and environmental win-win compared to existing extensive cattle management practices and other pasture intensification alternatives. Adopters of ICLS are well aware of the economic benefits of these systems – improved income, greater adaptability, and reduced environmental impact.

However, high upfront costs, greater managerial intensity, existing lifestyle preferences, as well as limited access to markets, credit, and technical information remain key barriers to ICLS diffusion. The sustainable transformation of Brazilian cattle production is also restricted by deeply embedded habits of specialization, extensive management, and aversion to taking on risk and debt. As farming systems experience ownership transitions, the habits, priorities, and knowledge gaps of cattle ranchers may become more favorable to ICLS adoption. The ongoing generational transition of farm operators could

be further stimulated by helping young farmers to obtain the capital and new skills needed to enter the farming sector.

Given the diverse barriers to ICLS adoption, the existing Brazilian agricultural development strategy of providing low interest loans for machinery investment and operational costs is insufficient to promote the rapid intensification of the country's extensive pastures. A comprehensive mix of positive and negative financial incentives is needed to motivate ranchers to intensify production: i) increases in demonstration farms using successful ICLS practices and widespread training seminars, ii) improved access and terms of public loans to better accommodate ICLS features, iii) improved supply chain infrastructure and machinery access for cropping systems, and iv) increases in positive incentives for intensification via value chain upgrading and payments for environmental services. In this way Brazil may harness its untapped potential for agricultural development and climate mitigation through intensification and recuperation of degraded pastures.

Acknowledgements: This work was funded by the National Science Foundation Grant #1415352, Harvard Sustainability Science Program, and Italian Ministry of Environment, Land and Sea. It was made possible through a technical cooperation partnership between the Brazilian Agricultural Research Corporation (Embrapa) and Boston University.

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