Tropical forage-based systems for climate-smart livestock production in Latin America

Tropical forage grasses and legumes as key components of sustainable crop-livestock systems in Latin America and the Caribbean have major implications for improving food security, alleviating poverty, restoring degraded lands and mitigating climate change. Climate-smart tropical forage crops can improve the livestock productivity of smallholder farming systems and break the cycle of poverty and resource degradation. Sustainable intensification of forage-based systems contributes to better human nutrition, increases farm incomes, raises soil carbon accumulation and reduces greenhouse gas emissions.

Agricultural development in Latin America and the Caribbean (LAC) depends on how effectively the region can address a number of challenges. Climate change affects the region as a whole, but particularly Central America and the Caribbean (CAC). This is mainly due to natural resource degradation, which has made the region especially vulnerable to changes in rainfall patterns, higher temperatures and higher incidence of natural phenomena such as hurricanes and droughts. Sustainable intensification of crop and livestock production with a natural resource management focus is likely to be the best way to confront climate change, reverse land degradation, improve food and nutritional security and alleviate poverty of smallholder farmers in LAC. Climate change predictions are expected to have far-reaching consequences for livestock production in LAC, mainly via (i) increased frequency of drought in some regions and excess seasonal rainfall in other regions, with negative impacts on native and introduced forage productivity; and (ii) heat stress on animals, reducing the rate of animal feed intake, causing poor performance growth and reducing animal fertility.

Livestock have served the poor in LAC as a social safety net, providing insurance or a "bank account" for times of need. Sustainable intensification of livestock production can provide regular food and income for improved livelihoods. There are approximately 450 million hectares of native and introduced pastures in tropical LAC. A major constraint to livestock production is the quantity and quality of forage production as a key feed source in ruminant systems. Overgrazing and a lack of suitable forage options that are better adapted to biotic (pests and diseases) and abiotic (edaphic and climatic) stress factors contribute to low productivity. Improper management (e.g., no fertiliser application and overgrazing) of pastures lead to soil nutrient depletion and pasture degradation, and limit livestock production. Improving pasture quality and productivity offers a readily available means of increasing food production and vitally needed protein production.

Production per animal unit in tropical areas of LAC is much less than in temperate regions. Increasing pasture productivity could help materially increase animal production. Easy access to high-quality forages and/or improved pasture management are crucial entry points for enhancing animal production and animal health, and it increases viability of genetic improvement of livestock. The sowing of better quality forages and better pasture management can improve forage digestibility and nutrient quality, resulting in faster animal growth rates, higher milk production and earlier age at first calving. Better nutrition can also increase cow fertility rates, and reduce mortality rates of calves and mature animals, thus improving animal and herd performance.

At least two alternatives exist for improving forage production in the LAC. One is to improve production of permanent pastures, and the other is to establish and maintain high yielding cultivated species on arable or potentially arable land in the three major agro-ecosystems of the region (savannahs, hillsides and forest margins). A third option would be a combination of the two. The potential for forage production in tropical regions is tremendous for both intensive and extensive types of production, although production costs are higher with proper grazing management technologies and the economic alternatives must be carefully considered. This article highlights the importance of tropical forage-based systems for climate-smart livestock production in LAC and presents the concept of LivestockPlus to stimulate interest and research in tropical forage production for the benefit of both agriculture and the environment.

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Development of climate-smart tropical forages

Forage grasses and legumes are complex crops, and their value for agriculture must be assessed in terms of the quantity and quality of downstream livestock products (traditionally milk and meat). In LAC, superior *Brachiaria* grasses have been widely adopted with large economic benefits. Experiences from Colombia and Brazil indicate that these pastures make a significant contribution to farmers' incomes by increasing animal productivity by five to ten times over native savannah vegetation. In Brazil, where about 99 million hectares are planted with *Brachiaria* grasses, annual benefits are believed to be as large as 4 billion US dollars (USD), while in Colombia, they are thought to exceed 1 billion USD. Estimates for Central America suggest that adoption of *Brachiaria* grasses generates an additional value of about 1 billion USD in one year, with 80 per cent of the gains accruing to the beef and 20 per cent to the milk industries.

The adaptation of *Brachiaria* grasses to low-fertility soils has contributed to their use for extensive, low-input pastures but also for intensively managed pastures. Although rotation of annual cropping with grazed pasture is not commonly practised, despite many potential benefits for both crops and forages, it is increasingly becoming an option for farmers in tropical America, above all in Brazil.

From *Brachiaria* breeding efforts at CIAT (Centro Internacional de Agricultura Tropical/ International Center for Tropical Agriculture), three commercial cultivars have so far been released: Mulato, Mulato 2, and Cayman. These three superior *Brachiaria*-bred cultivars combine high productivity, nutritional quality, resistance to spittlebugs, dry season tolerance, and adaptation to infertile acid soils (see photo below). But neither Mulato nor Mulato 2 are tolerant to waterlogging conditions. Recently, CIAT initiated efforts to breed for superior *Brachiaria humidicola* hybrids. These hybrids are required to diversify pastures in poorly drained or occasionally waterlogged soils that are estimated to cover about 7 per cent of the Cerrados (savannah) region of Central Brazil (approx. 17 million hectares) and major cattle production regions in the Amazon and the Atlantic regions of Central America. This work has been partially supported by the Ministry of Agriculture and Rural Development of Colombia and the private sector (Tropical Seeds; Dow AgroSciences).

Deep rooted *Brachiaria* grasses accumulate large amounts of carbon in deeper soil layers and contribute as such to mitigation of climate change. Forages can also contribute to the reduction of greenhouse gas emissions: feeding high quality forage grasses reduces methane emissions from animals per unit livestock product, whereas some *Brachiaria* grasses (such as *B. humidicola* CIAT 679) suppress soil nitrification by releasing from its roots a powerful nitrification inhibitor named brachialactone, thereby reducing emissions of nitrous oxide. This phenomenon is known as Biological Nitrification Inhibition (BNI). If a *Brachiaria* pasture with high BNI activity were to carry over to a subsequent crop, it might improve the crop's nitrogen (N) use efficiency and therefore its economy, especially for crops fertilised with substantial amounts of N.

To begin reaping the environmental and economic benefits of this improved grass on a large scale, CIAT and its partners are working on several fronts. Forage grass breeders are developing superior *B. humidicola* hybrids and seeking to accelerate hybrid selection through the use of molecular markers. At the same time, scientists together with smallholder farmers in Colombia and Nicaragua are evaluating already available *B. humidicola* hybrids and learning how to optimally integrate them into crop-livestock systems (see Box on page 15). In addition, researchers are using advanced simulation models and economic analysis to project where the new hybrids can be profitably introduced. The scope for integrating these materials into forage-based systems is quite large, especially in LAC, where various *Brachiaria* grass species are already the main feed resource for livestock production. This BNI technology could result in cropping systems with low nitrification and low nitrous oxide emissions thus decreasing N-input requirements for the subsequent annual crops and make agro-pastoral systems more productive and ecologically sustainable. Since *B. humidicola* hybrids offer the advantage of performing well

Photo: John W. Miles/CIAT

Cattle grazing on improved Brachiaria grass pasture.

on infertile soils, they should appeal to large numbers of smallholders across LAC. This work has been conducted in collaboration with JIRCAS, Japan and is also supported by Germany's Federal Ministry for Economic Cooperation and Development (BMZ).

Most herbaceous (e.g., *Arachis, Stylosanthes, Centrosema*), shrub (e.g., *Cratylia*) and tree (e.g., *Leucaena*) forage legumes have the ability to contribute N to the system and have high protein contents. These are deep-rooted to tolerate drought and give the ability to scavenge for nutrients in infertile soils. Tropical forage legumes not only provide high-quality animal feed but also enhance soil fertility, improve soil structure and water infiltration, increase soil carbon accumulation, favour soil biological activity, and contribute to weed control and soil conservation. Grass-legume pastures need no N fertiliser, thus offering both economic and environmental benefits. Legume-based pastures and, especially, cover crops/green manure can also increase the yield of subsequent crops. However, adoption of legumes for livestock production has been rather poor in the past and their dissemination is expected to continue at a low level unless economic incentives increase.

The LivestockPlus concept for climate-smart livestock production

To articulate how improved forages can lead to the sustainable intensification of mixed crop-forage-livestock-tree systems in the tropics and subtropics, CIAT and its partners have developed the LivestockPlus concept (see Figure), which comprehensively recognises multiple social, economic and environmental objectives. While minimising trade-offs, LivestockPlus emphasises synergistic interactions between people, soils, plants, animals, and the environment. The LivestockPlus concept aims to improve agricultural productivity based on four principles:

1) Selected sown grasses and legumes, if properly managed, are more productive than native or naturalised forages, and produce higher quality feed while allowing the release of land for alternative uses with low environmental footprints.

2) Well-managed sown grasses and legumes in combination with crop residues improve resource-use efficiency at farm level and produce more milk and meat, particularly in the dry season.

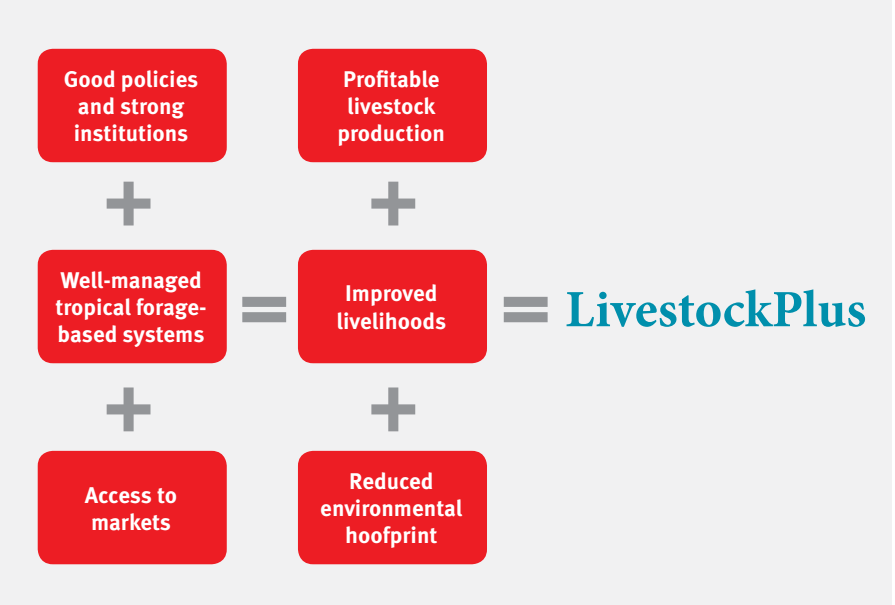
3) Sown grasses and legumes, especially when integrated with crops and trees under proper management, enhance system productivity, resilience and livelihoods. They also generate other ecosystem services, thereby reducing the environmental footprint per unit livestock product.

4) Multiple actions are needed to create enabling conditions essential for the adoption and widespread use of improved forage-based systems, including genetic improvement of livestock to match improved feeding, changes to regional and national policies along with increases of human and social capital.

Future challenges

The LivestockPlus concept proposes a practical pathway towards the goal of producing more agricultural products, with attention to livelihoods and ecosystem services for current and future generations. Increasing consumer demand for livestock products can and should be met by increasing productivity within the same region, mostly in the tropics and subtropics. Although livestock productivity could be increased using grain-based feeds, we favour intensification through forage-based systems based on goals of eco-efficiency, i.e., economic viability, environmental sustainability and social equity. To spark greater interest in and adoption of improved forages, however, the benefits of LivestockPlus need to be communicated to the global community. LivestockPlus seeks to double animal production on 50 per cent less land in the next ten years in some regions of a few countries where policies are favourable for adoption, freeing land for sustainable crop production, reduced deforestation and providing ecosystem services. Applying these interventions in resilient crop and livestock value chains should ensure economic gain and reduce poverty.

The LivestockPlus concept



Integration of forages to improve crop-livestock production – experience from Nicaragua

Photo: Aracely Castro/CIAT

Adoption of Brachiaria grass by smallholder farmers in the Condega region of Nicaragua.

Participatory action research with smallholder farmers from communities located in Somotillo and Condega municipalities in Nicaragua compared different treatments for improved systems and components (varieties of maize and bean in agroforestry systems and a forage option in a silvopastoral system) and their impacts on crop yields, forage and animal production parameters (grass biomass and milk yields) and ecosystem services (soil quality, carbon accumulation, soil erosion, biodiversity conservation). The approach involved farmers directly in the process, providing an opportunity to learn by doing, and allowing them to observe changes and benefits first-hand. This has also motivated farmers who were not participating directly in the project to adopt components or management (systems) or even the whole integrated crop-livestock farming system (agroforestry + silvopastoral) at an early stage.

Through field days with farmers, technicians, researchers, and representatives from the municipalities of Condega and Somotillo, research results and socioeconomic surveys have been presented and discussed with different stakeholders. The work, supported by the Austrian Development Agency (ADA), also facilitated visits from 100 farmers and technicians from other regions in Nicaragua, allowing to scale out the initiative to a broader range of beneficiaries. Validation of recommendation domains through workshops and ground truthing was done to facilitate further dissemination in other sites of Nicaragua that are suitable for adaptation and adoption of the integrated crop-livestock farming system. The project's integration of improved food crop and forage options to boost productivity and profitability, and particularly to enhance milk production during the dry season, has strongly encouraged early adoption of these alternatives by farmers, allowing them to see quick benefits as they could also recognise potential long-term environmental improvements.

Another innovative element of the project is the identification of socio-cultural and socioeconomic factors that can drive the adoption of eco-efficient crop-livestock systems. Establishing a collaborative learning community among farmers, women, and young people has been crucial, not only as part of the project's on-going research, but also to strengthen the communities' ability to carry on the farming system on their own and share their acquired knowledge and new experiences with others.