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Identifying and Characterizing Areas for Potential Forage Production in Rwanda

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Karama research station, Rwanda's national forage genebank (Photo: Georgina Smith/CIAT).

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Children enjoy milk fresh from the cow. Rwanda's "One cow per poor family" program (Photo: Stephanie Malyon/CIAT).

Introduction

Agriculture is the backbone of Rwanda's economy with more than 80% of the population involved in farming, contributing more than 30% to the country's GDP and 70% of its exports. The livestock subsector contributes 30% to the overall agricultural GDP. However, Rwanda's agricultural sector faces large challenges in terms of productivity. The population grew from 9.5 million people in 2005 to an estimated 10.8 million in 2011. If the current population growth of 2.8% continues, Rwanda would reach 26 million inhabitants by 2050, translating to a population pressure of 1,000 people per km^2 (NISR, 2011). Therefore, Rwandan policy making has renewed its commitment to intensification for sustainable agricultural development. A "productive and market-oriented agriculture" is the fifth pillar of Rwanda's Vision 2020, aiming to reduce the population relying on agriculture to 50% by 2020, practicing highly productive and market-oriented farming (MINECOFIN, 2000).

In terms of crop intensification, the Government of Rwanda has worked out specific policies for land consolidation, fertilizer, and improved seeds (MINAGRI, 2011), and terracing. Livestock policy promotes the adoption of improved cattle for dairy production and small livestock for meat. This involves investments in cross-breeding using artificial insemination (AI) with the ultimate objective of transforming the breed composition in favor of high-yielding dairy cattle genotypes. One of the strategies to accelerate rural poverty reduction is the "One cow per poor family" (GIRINKA) program (MINAGRI, 2006), which provides improved crossbreed cows to poor families. In 2009, the animal nutrition and livestock feeding sectors were given new direction with a strategic plan for improving livestock nutrition. Policy discourages traditional pastoralism in favor of intensification by means of confined grazing (zero-grazing, cut-and-carry) in most areas of the country. Fenced grazing is allowed only in Gishwati and the eastern lowlands. This calls for farm-grown forage grass and legume mixes with frugal supplementary concentrate feeding (MINAGRI, 2009). A feasibility study on a holistic Livestock Intensification Program (LIP) for Rwanda has been completed, which envisages an increased contribution of the livestock subsector to transformative growth of the economy through increased private sector participation in livestock sector development. The study indicated that, despite the increasing contribution of the poultry and piggery subsectors to livelihoods, ruminant livestock remain the major source of animal source foods and income (RAB, 2014).

Halfway through the implementation of Vision 2020, overall progress looks promising. UNDP (2007) reported that Rwanda was on the right track to achieving the Millennium Development Goals. Poverty nationally declined by 12% between 2005/06 and 2010/11 (NISR, 2011). However, Rwanda still remains below its agricultural potential for the main staple crops and livestock products. Only 28% are crossbred (MINAGRI, 2013). In addition, they are inadequately fed. As a result, milk yields can be as low as 300 liters per cow per year. Milk production is mainly limited by the availability of and access to year-round quality feeds, especially during the dry season (Lukuyu et al., 2009; Mutimura et al., 2013; Klapwijk et al., 2014).

During both the wet and dry seasons, a wide range of resources from on-farm and off-farm niches are fed to animals. These include collected natural grasses and herbs from roadsides and communal land; residues from cropland; banana pseudo-stems; improved fodder from farmlands, boundaries, and terraces; and uncommon fodder species from roadsides and marshland herbage. Home-made and commercial concentrates are rare feed resources (Mutimura et al., 2015). Especially poor Girinka farmers have difficulties feeding their crossbred cows, thus limiting productivity to 2–4 liters per cow per day (Klapwijk et al., 2014). The main challenges for animal feeding include limited land for quality feed production, limited capacity for rational use of the various niches for the development of a sustainable feed future, as well as limited capacity for rational use of available and accessible feed resources, especially crop residues and agro-industrial by-products.

Brachiaria Mulato II for seed multiplication and hay. Karama research station in Bugesera District (Photo: S. Malyon/CIAT).

Approach & Methods

The Agricultural Synergies Project began with the support of the Norwegian Development Agency (NORAD). The project aims at producing guidance on how to improve agricultural production in developing countries while reducing greenhouse gas (GHG) emissions. The project activities in Rwanda focus on pasture intensification, more specifically: (1) to estimate a realistic potential to improve land use and feed efficiencies in ruminant milk and meat production, while meeting the development goals set in Vision 2020 in light of land and other agricultural constraints and demands; (2) to establish a reasonable set of measures to achieve those goals; and (3) to estimate the change in GHG emissions that would result from achieving these goals. The results should ultimately inform the National Appropriate Mitigation Actions (NAMA) of Rwanda. As input for these calculations, areas for potential forage production need to be identified country-wide.

A reconnaissance survey was conducted from 19 to 20 March 2015. The objectives of the survey were to (i) provide qualitative insights into additional potential areas for forage production and (ii) produce recommendations for developing a method to identify and characterize country-wide potential for forage production. The sites visited stretched across Rwanda (Table 1, Figure 1). The field visits aimed at reviewing, discussing, and validating a preliminary list of potential niches and forage species. At each site, transect drives, farm visits, and key informant interviews were conducted. This was complemented with a visit to the Rwanda Agriculture Board (RAB) forage production site at the Musanze Research Station and selected on-farm *Brachiaria* (now *Urochloa*) trials.

A preliminary list of potential forage niches for additional feed production included terraces; understory in public woodlots; areas at government institutions (schools, administrative buildings); understory in private tree plots; marshlands; field and farm boundaries; intercropping with annual crops; roadsides; and forest buffer zones with farming activities to prevent forest encroachment. We hypothesized that the suitability of these niches for forage production depends on bio-physical suitability (soil, slope, shade, agro-ecology/climate); socioeconomic suitability (ownership, distance to farms, access to inputs, difficulties/obstacles); area size; and installment and management costs (labor, inputs).

Table 1. Summary of seed sources contacted.

Farmer/site	Longitude (°E)	Latitude (°S)	District	Sector	Cell	Village
Ngarambe	30.452	-1.981	Rwamagana	Kigabiro	Bwiza	Gitega
Gako	30.211	-2.350	Bugesera	Rweru	Nemba	Nemba
Nyirangarama	29.897	-1.679	Rulindo	Bushoki	Nyirangarama	Bubiro
Nizeyimana Wellars	29.687	-1.555	Musanze	Rwaza	Kabushinge	Gihango
Community cowshed	29.597	-1.523	Musanze	Kimonyi	Buramira	Kamugeni

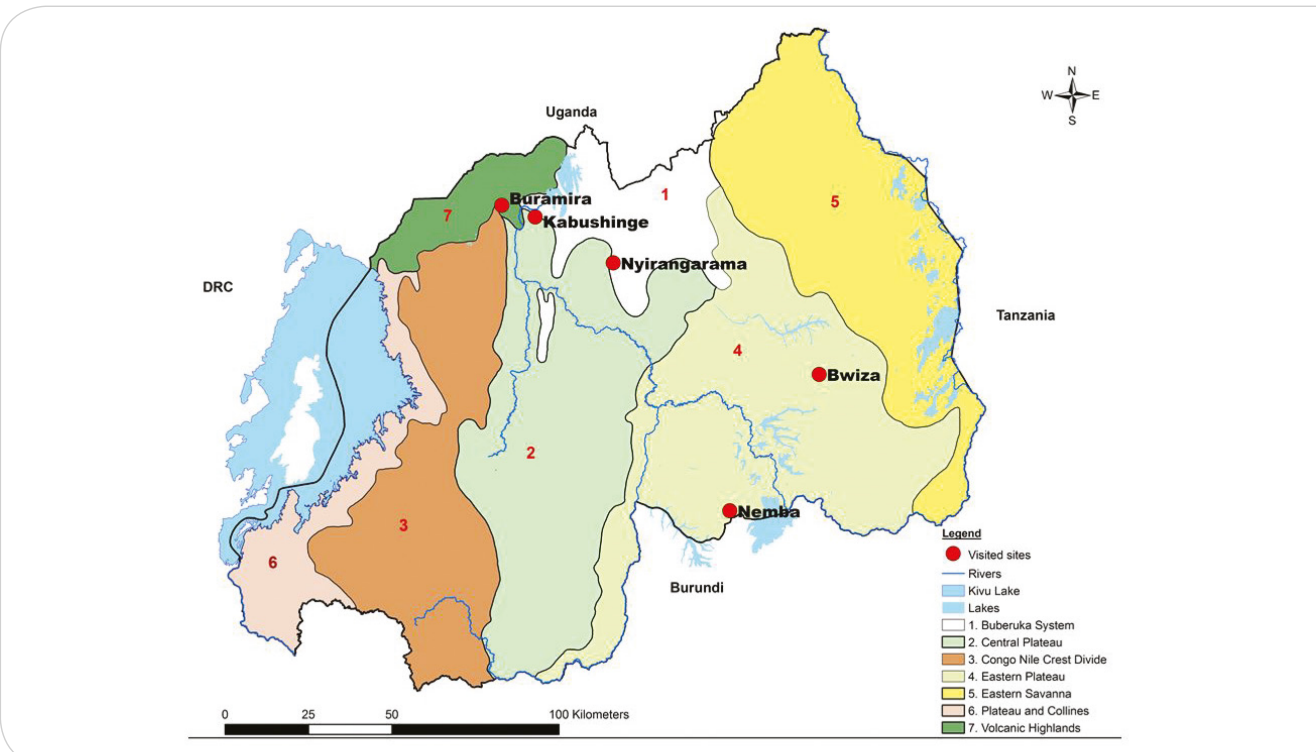

Figure 1. Sites visited during the reconnaissance survey in March 2015.

Potential Forage Niches

Land reclamation in the marshy areas

Marshy areas can be found in the numerous intersections between the undulating hills in Rwanda. Naturally, the marshy areas are dominated by common wetland vegetation. Traditionally, marshlands have been used as communal grazing reserves for the dry season. Currently, government policy discourages the practice in favor of reclamation of wetlands for rice production under the land consolidation policy and Crop Intensification Program (CIP). Nevertheless, marshlands provide niches for improved fodder production, especially Napier grass planted along the edges of the channels holding the soil in place, and maintain drainage (Figure 2). Marshland use for exclusive fodder production under CIP is an alternative policy consideration that can be examined for ecological, economic, and socio-political feasibility. Being a perennial grass, Napier is regularly harvested for cattle feeding with subsequent re-growth. A co-benefit with the strip setup is reduced mosquito larvae population densities by 75–88% in the water shaded by Napier grass (Wamae et al., 2010). As such, this indirectly contributes to lowering incidences of malaria transmitted by the insect vector. The rehabilitated land could be used for other high-value crops such as carrots and other vegetables.

Figure 2. Reclaimed marshy area in Rwanda (Photo: An Notenbaert/CIAT).

Woodlots with adjusted tree spacing

Across transects, forest plantations and farms were observed to be characterized by trees closely spaced together, often at less than 2 m. Under such conditions, and especially with the widely spread *Eucalyptus* species, mature woodlots can hardly support any growth beneath. Most likely, this is attributable to the extensive root systems and reduced sun flecks. Currently, policy discourages the use of forest ecologies as niches for fodder production, and access to opportunistic understory growth is prohibited for direct grazing or cut-and-carry. The concurrent use of space for trees and fodder production would, however, be feasible at wider spacing of trees that allows penetration of sunlight for shade-tolerant grasses, for example, some *Brachiaria* spp. (Rodrigues et al., 2014), Kikuyu grass (*Pennisetum clandestinum*), and *Digitaria* spp. or forage legumes (Nicodemo et al., 2015). This technological option can be considered as a synergistic alternative of land use for woody and herbaceous biomass production in forest areas without negative environmental consequences. This technology option is most likely feasible in privately owned woodlots.

Intercropping

Banana fields that are common in many households across Rwanda appear widely spaced and provide obvious niches for intercropping forages (Figure 3). Such forages could include herbaceous legumes such as *Desmodium intortum*, *D. uncinatum*, *Mucuna pruriens, Neonotonia wightii,* and vetch (*Vicia* spp.). These would not only provide soil cover but also contribute to improving fodder quality that is usually limiting on many smallholder farms. Annual forages such as oat (*Avena sativa*) and lupin (*Lupinus* spp.) could be considered for intercropping with bananas, especially in the highlands. After harvesting, the space could be allocated to another crop. The harvested oat could be dried and stored as hay, while lupin with dry seed could be ground and used to supplement animals. Further, intercropping Napier grass with bananas could also be feasible as long as the land patches are not needed for food crops. Therefore, the most favorable companion fodder crops need to be validated through participatory research for technical feasibility and social acceptability, including gender aspects (Kabirizi et al., 2007), though social issues are not likely to constrain adoption among farmers who have sufficient

Figure 3. Banana plot with some planted forages in the understory in Rwanda (Photo: An Notenbaert/CIAT).

land for food crop production and in position to spare some plots for the intercropping, but they may be few. However, more information on the technical feasibility, social acceptability, and sustainability of intercropping is important because currently there is a tacit policy disincentive to intercropping under consolidated land.

Farm boundaries

Boundaries demarcating farms could be planted with forages to serve for both fodder provision and delineating the farms. Fodder trees (*Calliandra calothyrsus, Leucaena leucocephala*, and other *Leucaena* spp.) could fit well in such niches and be maintained as hedges that are occasionally pruned to desired heights, and the clippings provide good-quality fodder for supplementing livestock. This technology has been encouraged in East Africa for more than a decade, with variable levels of success. There are tacit indications that it has been more widely adopted in Kenya than in other countries in the region because of the participation of research and extension support institutions (Wambugu et al., 2011).

In Rwanda, farmers have adopted this more for the provision of wood-fuel rather than fodder (Rushemuka et al., 2014). An additional consideration in Rwanda is the identification of fodder tree species for high-altitude areas where *Calliandra* and *Leucaena* are not ecologically compatible. The search for suitable fodder shrubs and trees for high altitude has identified *Sesbania* spp. and tree lucerne (*Cytisus proliferus* syn. *Chamaecytisus palmensis*) (Wambugu et al., 2011). However, these species would require adaptive research to fit them into production systems. A possible downside of cultivating all the edges with fodder plants could be negative edge effects on crop production, which could be exacerbated in small fields.

Soil erosion control structures

Areas that require preventing soil erosion, especially in the steep and sloping areas in both eastern and northern provinces, provide niches for planting forage grasses (Figure 4). The structures include terraces and contour bands. Grasses are usually characterized by fibrous roots that anchor and hold vulnerable soils in place, thereby reducing soil erosion, and from their perenniality provide fodder over time (Angima et al., 2002; Guto et al., 2011; Mwango et al., 2014). Grasses that are good candidates include improved *Brachiaria*, Napier grass or Guinea (*Megalothyrsus maximus* syn. *Panicum maximum*) grass and *Giant setaria*, or Guatemala grass (*Tripsacum andersonii*) in the higher areas. Despite its excellent attributes for soil erosion control, however, the use of vetiver grass (*Vetiveria zizanioides*) is discouraged because of its low forage quality that will not meet the demand of improved livestock. Further, the grasses could be planted along the shoulders of rural feeder roads for the same reason and minimize eroded soil blocking drainage channels.

Preliminary analysis shows that soil conservation structures are underused niches with an extraordinary potential for fodder production. On the other hand, rigid socioeconomic analyses must show whether farmers can be convinced to adopt improved forages on such, today, more or less idle land areas (Bizoza and De Graaff, 2012), or what incentives need to be in place for their better use. Multi-functionality may be one of the most important attributes for the likely adoption of a new practice under land constraints (McDonagh et al., 2014). It has to be recognized, though, that the effectiveness of grass strips in reducing soil loss may be low at establishment and the effectiveness increases as they become more established (Kagabo, 2013; Kagabo et al., 2013).

Figure 4. Grass strips on contours in Rwanda (Photo: An Notenbaert/CIAT).

Cropped land

Suitable niches on cropped land include consolidated lands under CIP and farmed land around homesteads. Some farmers can afford to spare land for fodder production, either for own use or for sale. Maximizing production from such plots would be important by using high-biomass fodder species. Some validated species in Rwanda include Napier grass, *Chloris gayana*, and *Panicum* spp. Oats and vetch could have potential as annual fodder crops but have not yet been tested. Attention needs to be paid to nutrient dynamics though. Napier grass often becomes less productive in biomass over time because fodder removal is not balanced with nutrient amendments. This could decrease the economic profits of potential fodder growers. The zero-grazing policy in Rwanda could increase the demand for planted fodder and, therefore, the development of fodder markets. Intercropping of Napier grass with leguminous fodder trees, shrubs, and crops could boost both the quantity and quality of fodder production, especially during the dry season (Figure 5). Lucerne (*Medicago sativa*) is also a good legume for establishing in sole plots, and with good management could provide fodder for a prolonged period. Evaluation of fodder sorghum, millet, and sunflower is in progress. A number of *Brachiaria* accessions have been evaluated (Mutimura and Everson, 2012) and could be more appropriate in areas where soil moisture is not a major constraint during most parts of the year. Another land-use option is promoting dual-purpose crops that produce food and fodder. For example, candidate varieties of dual-purpose sweet-potato have been evaluated for three agro-ecological niches of eastern Rwanda (Niyireeba et al., 2013). Consolidated lands also have potential of providing crop residues as animal feeds. In order to tap this potential, the construction of communal cowsheds in proximity to CIP sites is a policy incentive for promoting nutrient management in arable land and boosting livestock agricultural development.

Figure 5. Silverleaf Desmodium (*Desmodium uncinatum*) in Rwanda (Photo: An Notenbaert/CIAT).

Lowland and drier areas

The lowlands in the drier east (Figure 6) and south could have fodder trees (*Calliandra* and *Leucaena*) that could thrive even during dry spells. Their deeper root systems could enable them to reach soil moisture down the soil profile, especially during prolonged dry seasons, and sustain forage production. Further, fodder sorghum (*Sorghum bicolor*) could be considered in these areas. Since the lands are not in intense competition with other food crops, establishing sorghum in sole plots could be viable.

Some places in the north were observed to be highly rocky with no niches for forage production (Figure 7). In these areas, keeping livestock species that do not demand a lot of feed resources, such as goats or local cows, should be considered. Goats can serve as capital savings (Budisatria and Udo, 2012) and provide manure and meat. If promoted for milk production, social barriers to goat milk consumption will need to be taken into account, or market incentives for goat cheese production explored. Planting fodder trees in the areas could assist in feeding the small stock. However, agricultural land is much contested because of the rockiness of the terrain.

Figure 6. Confined grazing in northeast Rwanda (Photo: Birthe Paul/CIAT).

Figure 7. Beans produced on volcanic gravel in Rwanda (Photo: An Notenbaert/CIAT),

Karama research station in Bugesera District (Photo: Stephanie Malyon/CIAT).

Toward Upscaling Potential Forage Production to the National Level

Based on spatial data, a rough district-level estimate of the distribution of forage niches across administrative units in Rwanda could be made. A good starting point for this mapping exercise is the wide variety of spatial data already existing. These include, but are not limited to, road networks, land-cover classification, agro-ecological zones, climate variables, slope, and elevation. Further analysis of satellite data can yield more spatial layers, such as the terrace coverage maps. In addition, the availability of statistical data on farm size, income, and crop production could be explored and the ones at the lowest administrative level used.

Some ideas for calculating a rough estimate of the distribution of potential forage niches per district are given in Table 2. Clearly, these are just first ideas, currently not differentiated per agro-ecology or farming system. They need to be further refined through in-depth discussions with experts and farmers. In addition, the resulting estimates should be ground-truthed and validated through field observations across agro-ecologies and farming systems.

Table 2. Ideas for forage potential calculations.

Niche	Variable	Data source	Comments
Marshy areas	Area along drainage channels	Land-cover map	Could be calculated as x% of the wetlands area; observations in the field needed to establish reasonable "x"
Woodlots/plantations	Area for grassland production in woodlots	Land-cover map	x% of woodlands area
Banana intercropping	Area under banana	Crop statistics	x% of the area under banana; focus group discussions with farmers or field observations needed to establish reasonable "x"
Farm boundaries	Area of farm boundary	Agricultural statistics	Convert average farm size into estimation of the length of the farm boundaries; x% of this length * x meters
Soil erosion structures	Area of erosion structures	Kagabo et al., 2015	Length * 0.5 meter
Roadsides	Area of roadsides	Road network	Length of feeder roads * x meters; assumption: road network maps allow for identification of feeder roads
Fodder plots	Area for fodder plots	Agricultural statistics	x% of the farms of HHs with income > Y; some focus group discussions could provide a first estimate of x and y
Drier areas	Area for fodder production	Agro-ecological zones and land-cover map	x% of the semi-arid area under grass or shrub land

The factsheets of the SOFT tool (www.tropicalforages.info/; Cook et al., 2005) and the Feedipedia website (www.feedipedia.org/) in combination with GIS analysis could be used to produce suitability and potential productivity maps (ranges) for the forage species mentioned in Section *Potential Forage Niches*.

Overlaying these with the forage niche distribution maps allows for the calculation of ranges of overall forage production potential.

Brachiaria growing in a farmer's field, Okara Sector, Rwanda (Photo: Stephanie Malyon/CIAT).

Conclusions and Recommendations

Considering the niches and fodder species described above, there is potential to increase fodder production in Rwanda. To attain this, there is a need for awareness creation and promotion of forage cultivation, which is currently in limited practice by farmers. This could hinge on the land consolidation initiative in which an opportunity for considering forages among food crops exists at cell group meetings that decide on agricultural commodities in a given locality.

Diversifying forage species and cultivars at the farm level contributes to safeguarding against the risk of both biotic and abiotic stresses. Different species and cultivars are likely to be affected differently by diseases, pests, or weather. There is thus a need to not rely on one species or cultivar only, as has happened with Napier grass and incidences of Napier smut disease (caused by *Ustilago kamerunensis*) and Napier stunt (caused by phytoplasma) threatening its production. The presence of Napier stunt disease has already been confirmed in Rwanda (Nyirasengimana et al., 2013).

Promotion of forages should happen in tandem with improving markets such that the pull from the market end triggers increased demand for livestock products. This will in turn demand more fodder to sustain the production and this demand will provide the necessary incentive for farmers to allocate land to and invest in fodder production. For farmers to respond to the increased demand for forage production, the current constraint of forage seed availability will need to be addressed. The Karama station provides a good basis to address this but there is a need for more multiplication sites as well as training more experts. It would be interesting to explore the setup of commercial seed multiplication farms. Finally, investment should be made in good and sustainable information services, from which seed, forage, and milk producers could find up-to-date and relevant information.

It will also be important to train farmers on forage agronomy as the establishment, management, and conservation and use of a variety of forage species will be new to the farmers. Growing forages and harvesting from the field to feed animals inevitably contribute to nutrient mining and soil fertility loss. It is thus important to pay due attention to soil fertility management. Further, farmers should be trained on fodder planning such that, depending on the number of cows a farmer has, they would have an idea on the amount of fodder requirement in a year and appreciate the importance of fodder use and conservation.

Against a growing competition for land, there is a need for research efforts that support innovative forage development. Such a research program should not only focus on quality biomass productivity, but also aim at drought, disease, and pest tolerance responsive to climate change and variability, enhancing feed efficiency through strategic animal genetic improvement, reducing enteric methane emissions, and enhancing nutrient-use efficiency through strategic crop-livestock integration.

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