

A Science-Driven Approach to Sustainable Development of the Orinoquía Region

Purdue University's Orinoquia Initiative – Context, Vision and Goals



A SCIENCE-DRIVEN APPROACH TO SUSTAINABLE DEVELOPMENT OF THE ORINOQUÍA REGION

INTRODUCTION

The Orinoco River watershed of eastern Colombia is known as the Orinoquía. Located just north of the equator, the region is characterized by tropical savannahs, forested areas along rivers and sparse population. It is isolated by the Andes Mountains to the west, Venezuela to the north and the Amazon Basin to the east and south. At least since independence from Spain in the early 19th century, Colombians have believed that the area had the potential to become prosperous, but various development schemes have met with little overall success. Internal insurgency and unrest have largely undermined progress. The modest development that has occurred around certain natural resource-based industries (such as petroleum, cattle ranching, oil palm and rice) has generated concerns over environmental degradation and inequality of opportunity among citizens.

Purdue University's initiative, in partnership with Colombian government, educational and private institutions, paves the way for a master plan by examining the Orinoquía from a scientific perspective, including economic and social opportunities, physical resources, environmental needs and equity considerations. Purdue is pleased to engage in this effort based on 150 years of supporting economic, social and technological development in the state of Indiana, and its years of development and capacity-building experience worldwide. Using existing information, including 200 studies funded by Corpes Orinoquía and data available through the National Council for Economic and Social Policy (CONPES), Purdue faculty and staff seek to work with Colombian partners to develop a plan for improving health, education, roads, airports, communication and electrification. Hypotheses and scenarios based on this data would be rigorously tested and modified with Colombian partners, leading to a master plan for the long-term transformation of the Orinoquía.

The partnership is mutually beneficial to Colombia and Purdue. Colombia, and especially the people of Orinoquía, would benefit through a sustainable, equitable and environmentally sound transformation of the region. Purdue faculty, staff, and students would benefit through the research, learning and engagement skills they would hone in the process of creating and implementing the plan. Because universities are inherently institutions focused on the longer term, we hope to not only help co-create the plan but also play a key role in implementing it.

Colombia is the third-largest economy in Latin America, having recently surpassed Argentina, and it has strong economic growth prospects. It also has one of the most uneven distributions of income among OECD and Latin American countries, relatively low labor productivity and an economy tied to the boom-and-bust cycles of natural resource exploitation. The Orinoquía region, abundant in rivers and rich in biodiversity, could serve as a model for sustainable economic growth across Colombia and the Latin American region. Development in the Orinoquía ultimately could help provide opportunities for Colombians all along the social ladder as similar initiatives are adopted for other areas. Likewise, as modern infrastructure, education and growth of the formal business sector improves labor productivity in the Orinoquía, other regions could borrow from these plans for success. Finally, sustainable development projects could help smooth the boom-and-bust cycles not only in the Orinoquía but also around the rest of the country as similar ideas are implemented.

PURDUE'S STRENGTHS

Purdue University is one of the 10 largest universities in the United States. Faculty and alumni include Nobel Prize winners, World Food Prize laureates, and National Medal of Technology and Innovation honorees. Purdue University is a publicly supported state university with a global responsibility and mandate. Trade, travel and the increasing realization that we live on a small, rapidly warming planet have convinced the Purdue community and the people of the state of Indiana that our future is intimately connected to the rest of the world.

Purdue has over 60 years of experience in international capacity-building and economic development, with major initiatives in Taiwan, Brazil, Burkina Faso, Niger, Malaysia, Jordan and Afghanistan. We have a long history of educating Colombian students, and, over the past eight years, the university has developed strong relationships in Colombia. The Purdue community sees its engagement in Colombia as a partnership to make the world a better place for all, while at the same time furthering the goals of education and scholarship on its Indiana campus. Purdue offers an objective, third-party, science-driven perspective on development of the Orinoquía.

WORK PHASES

Initial Phase – Teams of Purdue faculty, staff and students in collaboration with Colombian partners review existing information, conduct needs assessments in each department in the region, develop hypotheses, analyze scenarios and draft a master plan. Purdue team members work with Colombian officials to plan pilot projects and develop rigorous monitoring and evaluation measures.

Implementation Phase – Using a mix of Colombian and international financing, the Colombian government and international funding/lending agencies such as the U.S. Agency for International Development, the World Bank and the InterAmerican Development Bank (IADB) would scale up projects to test their practicality. This would be followed by full-scale implementation, including institutional capacity-building for universities and research institutes in the region to support long-term success.

KEY INFORMATION NEEDED

Information in the following categories is key to a successful planning effort:

- 1) Physical resources
 - Climate and weather data – the expected impact of climate change
 - Soils data and mapping for crops, pasture and forest
 - Hydrological resources – availability of water
 - Geological data – petroleum reserves and mineral resources
 - Cultural and archaeological sites – mapping and descriptive narratives
 - Land use – current and expected future changes
 - Biodiversity – various landscape ecologies
- 2) Infrastructure
 - Transportation – within the region, links to the rest of Colombia, and export networks
 - Energy utilities – including electricity and natural gas
 - Health care and social services – hospitals, clinics and access to local health care
 - Information and communications technology systems – internet access and cell phone networks
 - Traveler and tourism infrastructure – hotels, restaurants and other resources
 - Educational institutions – all levels
 - Research facilities – including laboratories and research farms

- 3) Demographics
 - Current and projected population for the area – age structure, gender and income distribution
 - Educational level – current and expected changes
 - Professional/vocational distribution of the population – current and expected changes
- 4) Economic and financial sustainability
 - Structure of the Orinoquía economy by sector – agriculture, mining, food processing and other areas
 - Public finance – government funding for education, roads and other services
 - Labor force – current employment in region, trends and potential for in-migration
 - Banking and investment
 - Assessment of economic growth areas – feasibility studies
 - Policy environment for business

OUTCOMES AND VISION

We expect that the long-term outcomes from this science- and systems-driven planning process for Orinoquía would include:

- More sustainable economic growth and improved health and well-being for all of Colombia;
- Civil infrastructure for the development of Orinoquía;
- Preservation and enhancement of the biodiversity of Orinoquía for future generations; and
- Research, engagement and scholarship known and utilized worldwide to improve the capacity for sustainable development.

Our overall vision is of an Orinoquía with a prosperous, environmentally sustainable, market-oriented agricultural system; ample areas respected and set aside for ecological and cultural diversity; a robust, accessible education system at all levels; a growing knowledge-based economy with ubiquitous use of e-commerce, e-governance and online education; and the departments in the region operating cohesively and fully integrated into the future of Colombia. Petroleum and other natural resource extraction play a role, but do not dominate the region. The indigenous people of the Orinoquía, those internally displaced from the region and those attracted from elsewhere, have a stake in the economy and a clear voice in decision-making. Universities and research institutions build educational and research capacity, libraries and viable networks, initially to address the region's needs, but with the eventual goal of developing knowledge-based industries with a worldwide reach in such areas as the life sciences. Similarly, the importance of transportation in the development of the Orinoquía may foster growth of world-class engineering and innovation capacity in this arena.

Perhaps equally important is what this initiative will not do. It will not interfere with Colombia's internal discussions on development of Orinoquía and other regions. Our science- and systems-driven approach will complement current efforts within the country, offering options and consequences to partner with Colombian government agencies and other stakeholders. The faculty and staff of Purdue provide objective information and input because we have no direct stake in the outcome, other than a desire to see Colombia achieve its potential and the satisfaction of playing some small part in that success.

Details aside, our dream is that the partnership will evolve into a participative, inclusive collaboration in which Purdue teams work alongside our Colombian counterparts to identify and address needs through process-oriented, results-driven and scientifically robust means.

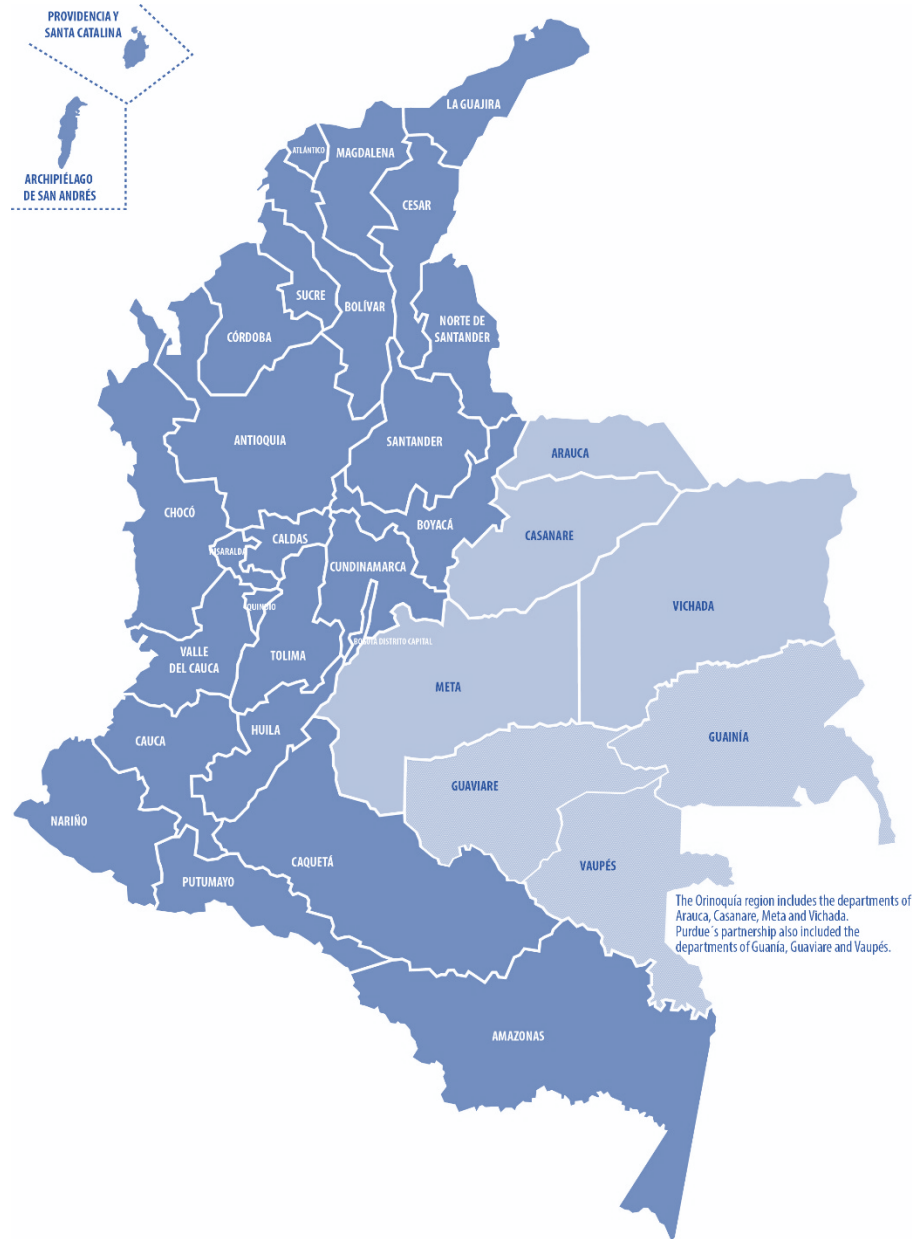
INTERDISCIPLINARY TEAMS AND THEMATIC AREAS

Implementation of the approach laid out above relies on the activities of five interdisciplinary teams working in a staged manner on the following thematic areas:

<p>TEAM 1: SUSTAINABLE AGRICULTURAL DEVELOPMENT</p>	<p>Assessment of Agricultural Opportunities: soil mapping and classification, Geographical Information Systems (GIS) assessment of agricultural potential, and cost/benefit analyses for rural development strategies</p> <p>Geomatics and Geospatial Science: classical land-surveying, digital mapping, photogrammetry, GIS, Global Positioning Systems (GPS) and remote sensing technologies</p> <p>Leadership, Civic Engagement and Agribusiness Development: social science dimensions of agriculture, including community leadership, conflict resolution around land use, and agribusiness development for smallholder farmers</p> <p>Food Security, Safety and Enhanced Nutrition: food process engineering to add value at the local level, distribution, and harvest and post-harvest loss prevention through parasite and pest mitigation</p>
<p>TEAM 2: ECO-TOURISM, BIODIVERSITY AND NATURAL RESOURCES MANAGEMENT</p>	<p>Preservation and Utilization of Biodiversity: soundscape ecology (use of sound recordings of natural environments to assess changes in biodiversity); informed decision-making on economic and social change; and microbial metagenomics, proteomics and systems biology</p> <p>Water Resources Engineering and Management: agricultural, urban and groundwater hydrology; watershed flow models; impact assessments on water quality and quantity; and aquaculture and fisheries management in riverine environments</p> <p>Human, Animal and Plant Protection: parasites, pest insects, weeds, pest nematodes, mites, fungi, bacteria and viruses that impact humans, livestock and crops</p> <p>Environmental and Ecological Engineering: remediation of contaminated soils and sediments, industrial and solid waste treatment, water and wastewater treatment, and urban and agricultural air and water quality management</p> <p>Traveler and Tourism Infrastructure: facility layout and design, menu development, food safety, menu nutrition/recipe development, business plan development, concept promotion, culinary tourism, agritourism, cultural tourism, destination brand development, international market trends and opportunities, and market development strategies</p>

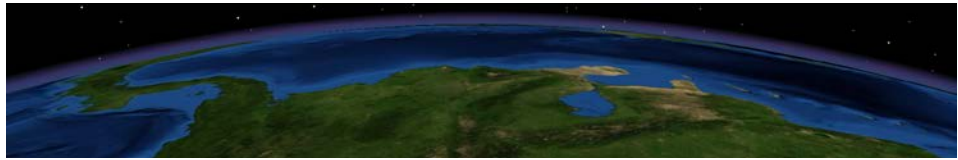
<p>TEAM 3: OIL AND ENERGY</p>	<p>Power and Energy Systems Initiatives: sustainable technologies in solar, wind and bioenergy; component design; life cycle analysis and smart grid technologies</p>
<p>TEAM 4: HUMAN AND SOCIAL CAPITAL</p>	<p>Integrated Systemic Educational Approaches: STEM (Science, Technology, Engineering and Mathematics) education from pre-kindergarten to college and graduate study; gifted education programming; and engineering-based service learning</p> <p>Transformative Learning: teacher preparation, professional development and leadership; university-level science and engineering for pre-college students; and contemporary curriculum approaches, such as participatory, service-learning and global/cross-cultural</p> <p>Higher-Education Capacity Building: knowledge-based hubs of expertise and development of local Extension services to provide university-based research insights to citizens and businesspeople</p> <p>Health Care and Social Services: Improving health care access, equity and services; population-based strategies for healthier lifestyles; and evaluation of health outcomes</p>
<p>TEAM 5: INFRASTRUCTURE AND NATURAL CAPITAL</p>	<p>Transportation Systems and Materials: planning and economics, complex transportation systems, intermodal transportation, transportation energy and sustainability, highway safety and policy analysis, advanced materials, and life cycles of road infrastructure</p> <p>Construction and Sustainable Buildings: project management, inspection, quality assurance, in-country supply chains, support infrastructure, construction engineering and management, design and analysis of energy efficient buildings, sustainable building design, and construction of indoor environments</p> <p>Information and Communication Technology (ICT) Systems: online education and training; web-based e-governance; mobile phone-based e-commerce, vocational and entrepreneurial training; data management; machine learning; big data for analytics, decision-making, security and privacy; IT workforce development, networking systems, software engineering and development; and hub-based ITC education at the university and K-12 levels</p>

The Orinoquía Initiative



A Science-Driven Approach to Sustainable Development of Colombia's Orinoquía Region

Our collective vision: an Orinoquía with a prosperous, environmentally sustainable, market-oriented agriculture with ample areas for distinctive ecological and cultural tourism activities.



1. Background

Purdue University and the Escuela Superior de Administración Pública signed a special cooperative agreement to provide cutting-edge research tools to support the region’s decision-making process and to promote understanding of the economic opportunities for agriculture and tourism in the region.

During the 14-month agreement, Purdue researchers led the Orinoquía Initiative in collaboration with Escuela Superior de Administración Pública (ESAP), Universidad de los Llanos (UNILLANOS), Universidad de los Andes (UNIANDES), Universidad Nacional de Colombia (UNAL), Agrosavia (formerly Corporación Colombiana de Investigación Agropecuaria, CORPOICA), Colombia’s Departamento Nacional de Planeación (DNP), the Ministerio de Agricultura y Desarrollo Rural and the Viceministerio de Turismo.

Area farmer associations; small, medium and large businesses; not-for-profit organizations; and other stakeholders were visited and interviewed to obtain vital data inputs for the Purdue-developed, analytical modeling tools that deliver various scenarios for economic development opportunities.

The Orinoquía Initiative partnership with Colombia focused on the following departments (states) in the Orinoquía: Arauca, Casanare, Meta, Vichada, as well as the neighboring departments of Guaviare, Guainía and Vaupés.

2. Opportunities and Challenges

Tremendous potential exists and numerous challenges face the citizens of the Orinoquía region. After the nearly 60-year civil war, labor productivity is relatively low, natural resources have been negatively exploited, and there is a shortage of services for enterprising communities to improve their economic status.

Economic development in the Orinoquía could provide opportunities for Colombians all along the entire socio-economic ladder. Modern

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Colombian Partners

MANAGING PARTNER

Escuela Superior de Administración Pública (ESAP)

TECHNICAL COMMITTEE MEMBERS

Departamento Nacional de Planeación (DNP)

Escuela Superior de Administración Pública (ESAP)

Universidad de los Llanos

Universidad de los Andes

Universidad Nacional de Colombia

Agrosavia

STAKEHOLDERS

Farmers and farm associations

Small, medium and large businesses

Not-for-profit organizations

Departmental and municipal governments



infrastructure, suitable education, and growth of the formal business sector and farmers' associations would help improve labor and productivity in the Orinoquía region and contribute to the country's overall development.

The Orinoquía region also contains extensive biodiversity, of which Colombians are justifiably proud. This biodiversity represents an opportunity for economic development of tourism, scientific inquiry, and ecosystem services. However, protecting the environment often is in conflict with other economic development motives. Finding the sustainable balance is a challenge to be addressed and to do so requires baseline studies and regional land-use models that describe the consequences of alternative courses of development.

3. Data Collection, Model Development and Training

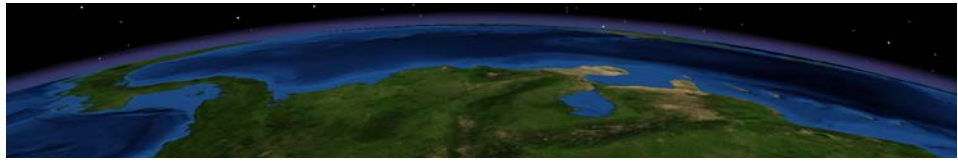
The Orinoquía Initiative team focused on data collection from tourism associations, farmers and farmers' associations. The information was then used in the development of analytical models and model frameworks. These tools and models can be used to inform decisions related to project evaluation, business planning, agricultural land use and answer various "what-if" questions related to resource constraints (land, labor, capital, etc.), new crops and crop systems, alternative technologies, business structures and commodity market values.

The efforts resulted in the delivery of a set of analytical modeling tools developed specifically for the Orinoquía region. In addition, training was provided to the Colombian officials in government, departments and municipalities to build capacity for informed economic decisions on the future of agriculture and tourism in the region.

3.1 Case Studies Inform Pilot Projects

Nearly a dozen case studies were completed for the Orinoquía Initiative. The farm level data inputs included crop selection, production costs, labor, capital use, yields over the production cycle and product prices.

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Linear programming models for agricultural activities in the Orinoquia were developed, applied and shared.

For sustainable tourism, the **Orinoquía Sustainable Tourism Development Model** was established for local tourism needs, and a portfolio of resources was created.

Pilot projects in both areas relate to value chain alternatives, logistical efficiencies and global and domestic markets.

3.2 Agriculture

Based on the case study analyses, five economically promising agricultural pilot projects were identified. The agricultural pilot projects will demonstrate practical applications of the analysis tools developed, extend knowledge to develop additional decision tools, and evaluate alternative courses of action and their probable consequences. They are intended as a guide for potential future investments in knowledge and capacity for the Orinoquía region.

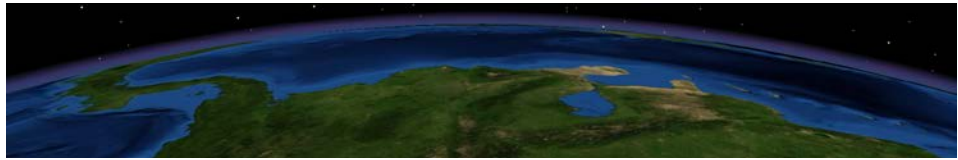
Five pilot projects on agricultural activities

- Opportunities for cultivating and marketing fruits in the Piedemonte;
- Improvement of beef production and ecotourism in the flooded savannahs;
- Integration of pork and grain production in the Altillanura for environmental and economic efficiency;
- Opportunities for growing and marketing cashews in Vichada; and
- Production of local foods for agricultural workers that require provision of food distribution.

3.3 Tourism

Three sustainable tourism pilot projects that highlight the region's priorities for land-use planning, governance and best practices were also identified.

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Three pilot projects for sustainable tourism activities

- Foundational activities for developing Yopal and nearby municipalities as a tourism destination;
- Market framework for developing the Llanos (Meta, Casanare and Arauca) as a tourism destination; and
- Development and integration of the tourism supply chain involving small and medium businesses for creating highly differentiated destination products and experiences.

4. Agriculture Case Studies

Purdue University developed and trained participants to use linear programming models to define priorities, evaluate farm-level profitability and identify constraints to further expansion at the farm level.

4.1 Analytical Models for Agriculture

For the Ariari, Piedmonte, Altillanura, Casanare and Vichada regions, models were developed for small, medium and large farm holders as indicated by their available resources and potential activities. The data for the farm enterprises was collected from a variety of sources including interviews with producers, Colombian university and research institutions, and producer associations. The analyzed data reflects the production costs, labor and capital use, yields over the production cycle, and product prices for each of the enterprises and the underlying technical efficiencies in production practices.

For agriculture, several linear programming models were developed for the Piedemonte and Altillanura regions. They were designed to evaluate portfolios of enterprises that would be complementary in their use of farm-level resources.

Linear programming models represent a practical method for teaching farm management and for training Extension personnel in assisting farmers in decision-making. These models, which may include local and family farming enterprises, can be used to train university students. Extension personnel can use the models to explore the viability of specific

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recommendations for potential changes in the economic and technical production parameters as they occur within a region.

Policymakers and Colombian university and research institution investigators were trained in the use of these models through a series of workshops. In particular, the workshops addressed how to tailor the models to different regions as reflected by different levels of productivity, alternative resource availability, different pricing for products and inputs, alternative enterprises and government policies.

The modeling tools coupled with adoption and training, enable fine-tuning of the analysis to reflect the local conditions where the pilot projects will be implemented. The data embedded in the existing models serve as the initial values to be added to in order to reflect local variations. For instance, two regions in the Piedemonte were modeled. The higher elevation was modeled for coffee and related crops. A principal fruit-production zone was modeled in the Ariari region. Expanding the number of farms involved in the modeling provides more details for the on-farm management and the off-farm labor and economic constraints.

4.2 Case Study Summaries

Modeling and Markets in the Ariari, Piedemonte, Altillanura, Casanare and Vichada

The focus of the Purdue fieldwork and modeling activities was to gather information on farming opportunities and management practices combined with market opportunities, marketing and finance research for the Orinoquía region.

Several Colombian institutions have collected valuable data on the physical and biological aspects of agriculture in the Orinoquía. The principal station of Agrosavia in the Orinoquía has a strong program of research in tropical fruits for the Orinoquía region, and UNILLANOS has developed expertise on the environmental and social aspects of the introduction of agricultural technology.

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Piedemonte Case Studies

The representative small farm in the Piedemonte was endowed with two hectares of irrigated and 15 hectares of non-irrigated land. Potential enterprises included guayaba, citrus, cacao, pineapple, rambutan, mangostino, avocado, coffee, oil palm, rubber, farmed fish, fattening of cattle, silage and dairy.

The promising portfolio of enterprises for this representative farm included pineapple on the irrigated land. On the non-irrigated land, citrus, farmed fish, mangostino, coffee and fattening of cattle were identified.

The representative medium/large farm in the Piedemonte was endowed with 50 hectares of non-irrigated land and no irrigated area. Potential enterprises included cacao, oil palm, pineapple, farmed fish, rubber, rambutan, mangostino, fattening of beef cattle, citrus, silage and dairy cattle.

The promising portfolio of enterprises for this representative farm included citrus, oil palm, farmed fish, mangostino, and fattening of beef cattle. The fattening of beef cattle also included the silage operation.

Altillanura Case Studies

The representative medium-sized farm in the Altillanura was endowed with 400 hectares of non-irrigated land. Potential enterprises included oil palm, rice, corn, soybeans, rubber, cacay nut, silage and beef cattle production. The promising portfolio of enterprises for this representative farm included rice, soybeans, rubber and cacay nut.

The representative large farm in the Altillanura was endowed with 2,000 hectares of non-irrigated land and the same set of potential enterprises as the medium-sized farm scenario. The same portfolio of enterprises (rice, soybeans, rubber and cacay nut) demonstrated promise for the large farm, but at a much larger scale of operations.

For agriculture in the Piedemonte and Altillanura, data on the production costs and labor were collected on a range of perennial crops, short-cycle food crops and livestock activities. Piedemonte perennial crop-data

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collection focused on fruit crops, oil palm, coffee, cacao, cacay nut and rubber. Fruit crops included guava, oranges, passion fruit, papaya, mangostino, rambutan, avocado and plantain.

In the Altillanura, there is high potential for combining annual crops with beef or pork production. Altillanura annual grain and forage crops were studied including rice, maize and soybeans. Perennial crop-data collection focused on oil palm, cacao, cacay nut, cashew and rubber.

However, it is also important to remember that there are many small farms in the Altillanura producing dairy and other activities for local sale as well as pineapples for local sale or in Bogotá. Many of these small farmers are also engaged in off-farm activities.

Since much of the finishing or fattening of cattle from the entire Orinoquía is done in the Piedemonte, it is important to identify technology for this sector. We expect silage production from various crops to be an increasingly important activity for high-production dairy producers and fattening operations, as well as for both small- and medium-sized farm activities. However, silage production does not appear to be a profitable activity as a single specialty for either small or medium farms but may be profitable when combined with dairy or finishing operations. Silage is increasingly pervasive in the Piedemonte with farmers producing or buying the silage for the dry season.

Many of the successful and profitable farms of all sizes are quite specialized, typically producing only one or, at most, a couple of closely related crop or livestock species for commercial sale. An example is milk and beef on dairy farms and one or two fruit crops while producing a wide range of products for home consumption and vegetables for local sale.

4.3 Summary

These models consistently identify various tropical fruits as being highly profitable. This profitability stems from the improved road connection to Bogotá, the peace agreement reached with the Fuerzas Armadas Revolucionarias de Colombia (FARC), and rising incomes in the urban areas of Colombia. Strategic public investments in Extension services that

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provide marketing and business training for farmers and farmer associations would accelerate the process of technology introduction and market improvement. The adoption of the models and training on them by university and Extension personnel would assure a healthier and more sustainable development process with sufficient human capital to meet the growing need.

4.4 Challenges

Health concerns

The market demand for very clean fruit with no insect or disease damage encourages high and indiscriminate use of chemicals with residual effects on the fruit (Dr. Javier Orduz, fruit specialist, La Libertad, Agrosavia, discussion, October 2017). The problem of excessive chemical use by the Ariari fruit producers and the dangers to human health need to be addressed with the use of improved biological controls and pest management practices.

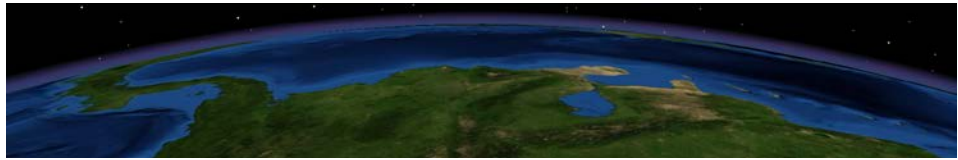
There is a research push in Agrosavia for biological controls and their increased use in the Piedemonte. Public intervention to ensure adequate health precautions would be beneficial.

Market Economics

Two economic issues need to be considered in developing future initiatives. Many small farmers are good entrepreneurs in the region. When the prices are high for a product like guava, driven by demand in Bogotá, many other farmers rush into this activity even though it requires substantial technical production knowledge, capital investment, and increased education to sell to the major market of Bogotá. The result is an oversupply relative to demand and falling prices over time.

The predominant farmer response is to get ready for the next high-price crop. For instance, established guava producers were observed planting avocado, which takes three to five years to begin production. The evidence of many small farmers reacting quickly to economic incentives and mastering the technical skills often provided by Agrosavia to increase production and their incomes is impressive.

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An alternative response would be to provide more timely information to farmers concerning demand and supply indicators. For example, if farmers were supplied data suggesting that demand growth is plateauing and had data on recent plantings, planting intentions, supply indicators and prices, then this information could temper the oversupply phenomenon and lead to more stable prices.

The second economic issue is the classic one of few buyers and many sellers when selling a homogeneous product to the wholesale outlet in Bogotá, which results in the perception that price fixing is a problem in these cases.

The ways to combat price fixing are for farmers to both collectively market and find alternative markets. In Bogotá, low-income consumers buy from the merchants pushing wagons and from the neighborhood stores. Middle-income shoppers buy from the corner groceries and middle-class-oriented supermarkets. High-income shoppers buy from the luxury supermarkets with their many imported and national goods.

With farmers' associations controlling for quality and selling larger quantities, the associations could sell to the neighborhood groceries and even to the supermarkets if they could provide regular quantities of high-quality product.

Of particular concern, the central farmers market in Villavicencio was torn down and the new market was relocated out of town, making it difficult for low- and medium-income consumers to shop there. The fruit production from the Piedemonte travels to Bogotá and returns to Villavicencio with minimal value added. The result is that low- and medium-income consumers struggle to buy directly from farmers. They are constrained to centrally located supermarkets that purchase from the wholesalers in Bogotá.

Silage and Pasture Renewal in the Piedemonte and Altillanura

Besides fruit production, another critical input for farmers includes dairy and cattle fattening operations in the Piedemonte. The production of silage could be a viable input to improve the nutrition and productivity of dairy cows and to prevent or moderate the weight loss cattle suffer during the dry season (December-March). Silage production would

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especially benefit the more efficient, middle-size dairy and beef producers (50 to 100 ha in the Piedemonte) throughout the Orinoquia.

The use of improved pastures from the research of the Colombiano Agropecuario (ICA) and the Centro Internacional de Agricultura Tropical (CIAT) is pervasive now in the Orinoquia, but they are often degraded and producers complain about high costs of renewal. Ranchers and dairy producers search for other alternatives to inorganic fertilizer. Deep plowing of hardpan soils from the cattle trampling is also very expensive. Alternative pasture-management approaches may help maintain improved pasture quality over time, but rotation is also generally practiced.

5. Agriculture Pilot Projects

The five agriculture pilot projects would focus on distinct enterprises in specific locations. They include opportunities for fruits in the Piedemonte and in the foothills of Casanare, beef production and ecotourism in the flooded savannahs, integration of pork and grain production in the Altillanura, opportunities for cashews in Vichada, and production of local foods for agriculture workers.

The linear programming models developed by Purdue play an integral role in product selection and production efficiencies and in understanding access to global and domestic markets. With the promotion and adoption of the analytical tools as well as continued training on them, Colombian university and Extension personnel would be prepared to play an essential role in facilitating and educating farmers to take advantage of the analytical modeling tools that are essential to the success of the farmers.

Training Colombian university and Extension personnel to work directly with the farmers on a grass-roots level would ensure the sustainability and success of the projects beyond Purdue University's direct involvement in the region. It is our vision that the adoption of the analytical tools would improve efficiencies, increase market understanding, and positively impact Colombia's agriculture for the future.

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5.1 Fruit Production in the Piedemonte and Casanare Foothills

Small and medium farmers who are predominant in the foothills of Meta and Casanare. Property values are increasing rapidly especially in Meta, so intensive production is appropriate.

Fruit production is a labor-intensive small-farm activity with rapidly expanding markets in urban areas. Fortunately, Agrosavia La Libertad has an excellent and long tradition of experimental work on a wide range of tropical fruits from all over the world and regularly does various types of farmer training at the experiment station and on the farm.

Farmers rush into production when profitable activities are identified. However, farmers need to specialize to market high quality and quantity to the Bogotá market. They also need to prepare for the continuing price declines over time by acquiring technical and marketing knowledge about the next fruit crop. A value-added alternative for fruits could be juice from the latest high-priority crop, such as passion fruit. This would be a good activity for expansion for the farmers' associations, which have a successful model in the fish producers' associations. Fishpond production is also a highly profitable activity and expanding rapidly in the Piedemonte.

With increased funding, Agrosavia could expand its Extension activities or collaborate as the critical component of a regional Extension service. More inputs on marketing and business methods are needed to supplement the technical training.

The introduction of greater local economic inputs for the region could take advantage of the multi-disciplinary efforts already undertaken in higher education and technical institutions in the region and with UNILLANOS and its sustainable agriculture program.

Additionally, a long-term objective could be a master's degree program in agricultural economics by working with the Ministerio de Educación Nacional de Colombia in a supporting role with its rural education emphasis and through the existing education exchange agreements among Purdue University and Colombian institutions

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5.2 Beef Production and Ecotourism in the Flooded Savannahs

The Casanare Department has extensive flooded savannahs that are inundated with water for up to eight months of the year. Three distinct landforms in the flooded savannah influence land suitability. Bancos, making up one-third of the area, are riparian, with acidic, sandy loam soils with moderate to good drainage. In contrast, the esteros are the lowest areas in the landscape positions, with finely textured, poorly drained soils. Water collects in the esteros and primarily evaporates. In between are the bajios, higher in organic matter but still acidic with moderate drainage that make up approximately 50 percent of the area (Rivas et al. 2002).

Many of the current agricultural production practices appear to be unsustainable due to challenges posed by this landscape, including water availability during dry periods, soil quality and a general lack of sustainable water-management planning. At the same time, farmers are reporting increasing climate extremes and water scarcity during the dry season, making water management a critical part of future planning in this region. Uncertainties with climate change and with water availability during the dry periods are of great concern to farmers on how they will affect cattle production and the potential loss of biodiversity.

Sustainable land- and water-management strategies are critical to achieve agricultural and economic development, mitigate risks associated with future climate change and variability, and maintain biodiversity in the region.

There is a need to evaluate formal and informal social institutions that influence management of shared water resources. Purdue-developed modeling tools could assist with studies already in progress by Colombian institutions. The evaluation would identify geospatial and in-situ data needs, develop a strategy for monitoring infrastructure, utilize co-production principles to identify needs, and develop simulation models and tools that could be utilized to make agricultural production decisions in the regions.

Modeling tools would assist with decisions like the mix of crop and livestock enterprises, improved water management, production

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technologies, and improved land and pasture management. Once developed, the tools can be utilized to facilitate alternative planning frameworks that would encompass diverse stakeholder perspectives for sustainable water and agricultural development in the region.

Additionally, the simulation and modeling tools would inform decision-makers on the best projects that demonstrate how beef production can be integrated with production of agricultural crops such as rice and oil palm, while maintaining the rich biodiversity in the region and utilizing the integrated systems to promote ecotourism in the region.

5.3 Integration of Pork and Grain Production in the Altillanura

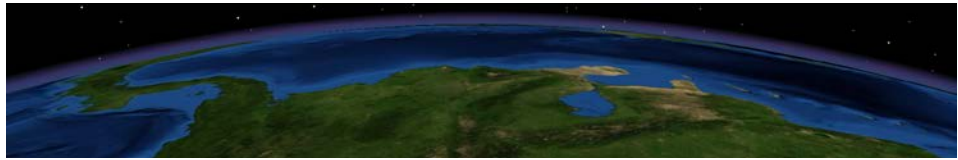
Key concerns facing integrated pork and grain production in the Altillanura are related to local farmer opposition to contract production mechanisms and concerns about environmental degradation from intensive crop production and fertilization. Efforts in the pilot project must focus on these aspects to be successful.

With contract swine production emerging throughout the world as a dominant economic model, farmer concern about such approaches requires an educational approach that focuses on the broad range of contract types and their implications for net returns and risk.

Farmer and rural education should follow a model of alternatives and consequences rather than advocacy for a particular market structure such as contract farming or open-market transaction. That is, relevant information should be carefully developed that explains the alternative contract types typically used to coordinate swine production as well as the associated economic consequences for farmers who adopt those mechanisms. Decisions about adoption must be made by the farmers and processors but ideally with complete information about consequences.

The environmental dimension would be addressed by measuring and documenting the synergies represented by jointly determining the optimal spatial cropping patterns, crop rotations, use of manure as a fertilizer for crops, swine diets, and employment of technologies in feeding, cropping and manure disposal. All of these require extensive data acquisition in order to parameterize a mathematical programming model that addresses farmer decisions, alternative environmental

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policies, feasibility of alternative technologies, optimal alternative enterprises, and how different business structures (contract types) affect farm-family well-being and environmental outcomes.

Purdue University could support ongoing rural education efforts in Colombia with deliverables that include a management tool in the form of a mathematical programming model as described above. Support would include a curriculum to educate farmers and others about the likely consequences of alternative vertical-coordination mechanisms (contracts and other farmer-compensation alternatives). Workshops focused on the use and parameterization of the programming model and the alternatives and consequences of vertical coordination would be included in the deliverables. Data concerning manure nutrient fates under alternative systems of handling and land application to various key crops would be required as well. Key site specific management issues can be facilitated by use of GPS and site specific farming technologies.

5.4 Transportation and Options in Vichada

As one travels from Meta into Vichada, the quality of the roads declines substantially, making transportation a major constraint especially in the rainy season. Many of the soils are sandy, raising the costs and lowering the efficiency of fertilization. However, the rapidly increasing land costs in Meta have been pushing both farmers and ranchers into Vichada.

A preliminary analysis of Vichada's agricultural opportunities suggests that cashew may be a good option. Processed cashew is a relatively high-value product that may be profitable even with high transportation costs.

Cashew prefers sandy soils, and international demand for processed cashews has been increasing. The economic viability of and financing for a processing factory in the region would still depend upon the costs of road (or river) transportation to get the cashews into international markets. Because cashew is shipped dry, it could be stored until the Meta River is high enough that barges can reach Puerto Gaitán.

It is a challenge to identify complementary enterprises with the cashew option. Labor requirements are relatively high for cashew – 0.76 man-days per hectare per month from May through October and roughly one man-day per hectare per month from November through March. The

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existing activities in Vichada such as rubber, oil palm and cow-calf enterprises use labor fairly uniformly throughout the year and do not provide synergies with cashew production. As with cashew, both oil palm and rubber require processing facilities nearby and/or lower transportation costs. Cattle can be walked out in the dry season to be auctioned for finishing, principally in the Piedemonte and the Altillanura.

Various forestry products and some tropical fruits are also options in Vichada. However, the transportation costs remain an issue.

Using amended versions of the linear program could create new case studies to better understand how these various alternatives fit together. Furthermore, cashew-processing technology would need to be examined for suitable application in the region, and the potential uses of processing byproducts should be explored to enhance sustainability.

Additional work is needed to identify enterprises that could profitably complement cashew in the use of farm resources. One potential asset of the region is the Orinoco River. If barge traffic to Puerto Ordúz became viable, that could make a number of additional enterprises, e.g., cacay nut, rubber, irrigated oil palm, economically feasible.

5.5 Food Supply for Agriculture Workers

There is an opportunity to add value to farmers' products, reduce costs and potentially increase quality for the agriculture workers by organizing the local supply of fresh fruits and vegetables delivered directly from farms to the agriculture workers and/or processing facilities.

Case examples include the palm industry. In many cases, the palm industry provides housing and food for their workers who are on site for nine to 12 months. If local fruit and vegetable farmers in the surrounding area could be organized to provide produce to the palm operations, it could potentially create a win-win situation for both parties by avoiding transaction costs of intermediaries and transportation. Such an arrangement would create an additional market for farmers with potentially higher prices than they would otherwise receive, and it would give the palm operations a potentially lower-cost source for acquiring fruits and vegetables.

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Several things are needed to ensure the success of this type of arrangement. First, both the farmers and the agriculture workers need to understand that a partnership can only be beneficial if they are both willing to share the gains from the avoided transactions costs. Second, the farmers and farm operators need to plan jointly on the production and harvesting in order to achieve a reasonably constant supply and diverse set of fruits and vegetables throughout the year. Ideally, this would be a long-term collaboration with a commitment by farmers to produce and deliver a variety of high-quality produce at frequencies desirable by the farm operation. The farm operation would need to provide reliable payments and potential transport of produce. Third, technical advice would be needed to identify vegetable and fruit enterprises that would fit together in a production system for the farms without exceeding their resource capacities and without oversupplying individual products to the operation. Farmers would also need technical agronomic guidance to ensure that the farms are successful. Ideally, production would be coordinated across all supplying farms so that a steady supply of a diverse set of crops is achieved. This activity as a model could be extended to other sites of small-population concentration.

6. Purdue Sustainable Tourism Fieldwork

The Orinoquía region in Colombia offers unique natural and cultural attractions such as El Tuparro and Sierra de la Macarena national parks. In recent years, there has been limited tourism in this region, but new developments are expected. Recognized as an engine for regional development in Colombia, tourism practices can be organized to ensure that community members obtain direct social and economic benefits as well as indirect benefits from the provision of tourism services. It is shown that ecotourism/agrotourism projects reduce rural poverty and support economic development within indigenous communities.

In a series of industry meetings, the Orinoquía Initiative team met with tourism industry members from organizations in Yopal, nearby San Juan de Palenque, in Meta, and the surrounding region to discuss effective

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ways of enhancing tourism offerings to enrich economic development and to ensure social and environmental benefits for the host destination.

The collaborators discussed opportunities in destination and select niche markets, such as heritage celebrations for the Los Llanos area, birdwatching, and cultural tourism.

There is considerable enthusiasm for tourism in the Orinoquía and evidence of consumer demand for the region. Tourism has the potential to support economic goals while encouraging environmental and cultural conservation as well as heritage preservation. However, these positive outcomes require deliberate action by a variety of actors within the destination system. Similarly, the peace dividend for tourism will require deliberate strategies including training and capacity building.

6.1 Colombian Efforts in Sustainable Tourism

Colombia has embraced the adoption of sustainable tourism for more than 10 years and has made substantial progress in the tourism system. Elements contributing to success are:

Government Support – National-level programs including infrastructure programs; agencies including the Ministerio de Comercio, Industria y Turismo de Colombia (MinCIT) and DNP; and departments and municipalities are developing programs to support tourism.

Legislative Framework – Colombia has enacted some regulations directed at tourism operators to require small businesses to adopt sustainability practices. An assessment tool based on Global Sustainable Tourism Council (GSTC) criteria would assist government leaders in assessing the comprehensiveness of their current regulations.

Destination Marketing Support – The MinCIT has programs to support the tourist-corridors strategy that incorporates “Corredor de Los Llanos” (Meta, Casanare and Arauca) and “Corredor de la Orinoquía” (Guainia, Vaupés, Guaviare and Vichada) and inclusion in tourism and peace initiatives.

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Local municipalities in the Orinoquía have established tourism offices that provide direct contact with small-tourism businesses and are a significant resource in each destination.

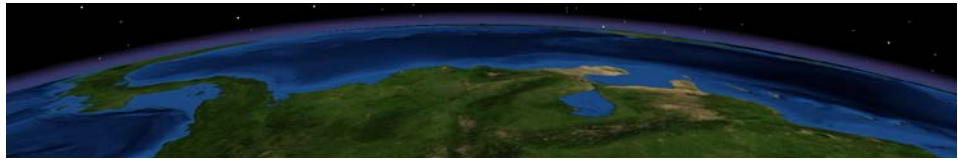
Natural Attraction Management – Colombia’s National Parks system has adopted best practices in natural resource management including ecotourism practices. As visitor numbers increase, investment in infrastructure to protect these locations and manage visitors will be necessary.

Destination Clusters – Enterprise clusters working to develop destinations and attract visitors are emerging. These clusters comprise primarily small, entrepreneurial family businesses. In many cases, these businesses have been developed to supplement other forms of income, primarily farming. Cluster development programs have been adopted by both DNP and MinCIT to support tourism development.

Sector-based or Niche-market Clusters – There is interest across the region for the development of products targeting specialized niche markets including birdwatching and sports fishing. The development of network clusters to address these specialty markets would provide greater market impact for these individual products. DNP has been instrumental in the development of market-based clusters in several areas of the Orinoquía.

Micro/Small Business – The development of tourism in the Orinoquía provides opportunity for many small businesses. Tourism businesses in the region tend to be small and family-owned. Many have been attracted to tourism as a means to supplement income produced from agricultural activities. Many of these business managers are new to tourism and have training and capacity-building needs. Challenges include marketing, product/experience delivery, and customer service as well as general small-business development and operation. While traditional small-business structures are most common, some communities are adopting variations of community-based tourism models (e.g., White Cliffs community near San Juan de Arama).

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6.2 Challenges

Tourism development can potentially have negative impacts on destination communities. For instance, tourism expenditure can “leak” from the community with little benefit to local business, seasonal demand for tourism can cause challenges for business viability and employment, and increased numbers of visitors can stretch local municipalities’ resources and stress local ecosystems and natural attractions. Increases in tourism also can “commodify” local culture and lead to increases in crime. Sustainable tourism practices are designed to minimize these impacts and provide destination communities a framework to ensure they benefit from tourism.

6.3 Orinoquía Sustainable Tourism Development Model and Tourism Knowledge Resources

Orinoquía Sustainable Tourism Development Model

The Orinoquía Sustainable Tourism Development Model has been modified for local needs and is based on the Global Sustainable Tourism Criteria (GSTC). The model maximizes the economic and social benefits of tourism with attention to both direct providers of tourism products, e.g., hotels and lodging, tour operators, commercial attractions, and indirect suppliers to tourists such as food, local artisans and cultural activities. Indirect suppliers can significantly extend the benefits generated from tourism operations. Efforts to enable these suppliers to deliver products to tourism operators is an important principle of the work.

The Orinoquía Sustainable Tourism Development Model incorporates a systems approach to guarantee sustainable tourism. From the perspective of the destination, tourism takes place in a series of integrated systems: tourists, companies, cluster destinations and the broader social/economic/political system. To maximize the benefits of tourism, each of these systems must perform key tasks that maximize the benefits of tourism and/or reduce tourism costs. To have optimal performance, each level of the system must function effectively and support the others. This model addresses the tasks and functions at each level of the tourism system required to achieve sustainable tourism.

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Applications of the Orinoquía Sustainable Tourism Development Model are expected to increase significantly in coming years. The tourism model provides a useful framework for analysis of the issues facing the region and contributes to the implementation of sustainable tourism practices.

Tourism Knowledge Resources

In addition to the Orinoquía Sustainable Tourism Development Model, Purdue's sustainable tourism team are producing a portfolio of resources for members of the destination systems in the Orinoquía. The resources include self-assessment tools, "tip" sheets, case studies and white papers. These resources will be available to government leaders (governors, mayors, etc.), destination marketing professionals (tourist officers for municipalities, departments, etc.), small tourism businesses, and specialty businesses such as agrotourism or birdwatching.

7. Sustainable Tourism Pilot Projects

Three pilot projects for sustainable tourism activities are centered on the destination incubators and sector-based or niche-market clusters and the design and integration of supply chains.

The pilot projects include:

- Foundational activities for developing Yopal and nearby municipalities as a tourism destination;
- Market framework for developing the Llanos (Meta, Casanare and Arauca) as a tourism destination; and
- Development and integration of the tourism supply chain involving small and medium businesses for creating highly differentiated destination products and experiences.

7.1 Foundational activities for developing Yopal and nearby municipalities as a tourism destination

Foundational activities will examine the integrated systems involved in tourism activities. The Orinoquía Sustainable Tourism Development Model will be employed to address the tasks and functions at each level

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of the tourism system that are required to achieve sustainable tourism for all stakeholders in Yopal and nearby municipalities.

7.2 Market framework for developing the Llanos (Meta, Casanare and Arauca) as a tourism destination

Pilot projects would build on our foundational work and provide ongoing technical support for destination and sector development. These projects would be customized to the specific needs of the destination, and discovery from the projects would be transferable to other destinations and locations.

Destination Incubators – The emergence of destinations within the Orinoquía provides opportunities for small businesses directly and indirectly involved in tourism. These small businesses and the destinations systems that support them face significant challenges as they establish and develop their businesses, develop markets and create visitor experiences. The organizations require ongoing support as the destination develops. While each destination and business face similar issues, a customized response to the specific needs of each location will be optimal. The pilot projects would involve a collaborative planning process to develop tourism in the destination as well as ongoing technical support for destination leaders and product participants.

Possible destinations for the pilot “incubator” projects include Lejanias, San Juan de Arama, La Macarena/Caño Cristales, Puerto Carreño/Tuparro, and Yopal.

Sector-based or Niche-market Clusters – Development of specific market sectors of tourism across the Orinoquía region is promising. The pilot projects would take a similar approach to the above and focus on the specific needs of the unique market sector.

Possible sectors include agrotourism, birdwatching and sports fishing. Development of these market sectors could integrate with possible agricultural opportunities in Meta, Casanare and Arauca identified in the agricultural pilot programs.

Both the destination and sector-based clusters pilot projects would include the following support and management advice:

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- Collaborative cluster process support. The process that brings together the key players in the development of the destination.
- Technical support of both destination marketing operations and operators, including marketing and product development support.
- Project monitoring systems and performance management advice.

7.3 Developing the tourism supply chain

The inclusion of small and micro-enterprises is a key strategy in maximizing economic benefits of tourism and providing authentic cultural experiences. This pilot provides critical capacity/skill development for small businesses including artisans, food suppliers and farmers seeking to benefit from tourism directly or indirectly. The project focuses on three inter-related issues.

- Business planning and business development
- Product and experience development
- Marketing

The pilot project supports the development of highly differentiated destinations providing authentic, unique experiences. It also builds on the established practices of several destinations and provides an important supplement to the work of NGOs and MinCIT in these regions.



8. Findings from the Orinoquía Initiative

For a range of social, environmental, economic and political reasons, Colombia would benefit from a mix of large, medium and small farms and businesses in the Orinoquía region. Medium- and small-scale businesses are already competing in many domains and could compete more effectively with a modest level of applied research-Extension investment.

Need for an Extension Service – In many cases, the greatest constraint to the development of small and medium agricultural and tourism businesses in the Orinoquía region is the lack of an Extension Service and associated applied research. This gap is especially evident in farm- and business-level management functions such as marketing, finance and personnel management.

The most functional Extension Service system in the Orinoquía region for agricultural activities is operated by commodity federations, but that system is focused tightly on technical issues and is limited to information and training about the target commodity. For example, a medium- or small-scale palm oil producer who also raises cattle would need to tap two different organizations for technical expertise and has few or no options for addressing marketing, finance and personnel objectives.

Agrosavia, universities and NGOs do applied research on the problems in the Orinoquía region and serve some stakeholder groups. However, the organizations do not have the mandate or the resources to extend findings throughout the region.

In general, technical and higher education in the region has only tenuous links to agriculture and tourism. Educational institutions are not well connected to research or Extension beyond their own systems, although they sometimes will do their own Extension activities.

For tourism, Colombia's vocational training system (Servicio Nacional de Aprendizaje or SENA), universities, foundations and NGOs are providing some training, but much more is needed. The Orinoquía desperately needs an Extension Service system that benefits from the synergies among education, research and the Extension services.

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Purdue University and its faculty have experience in capacity-building exercises with partner universities around the world in developing synergistic teaching, research and Extension functions.

Optimal Scale – Although the economically optimal scale varies by activity, in general, there are no inherent economic advantages for large-scale agricultural and tourism businesses over medium- and small-scale alternatives in the Orinoquía.

Most of the competitive advantages of large-scale organizations in the Orinoquía seem to be institutional. For instance, large-scale enterprises can hire consultants for technical advice and are less constrained by the lack of an Extension Service. However, the production costs of large-scale farmers are very high due to low land productivity, management difficulties and labor turnover.

Tourism development must recognize not only economic but also social and environmental goals to optimize benefits for the region in terms of optimal scale.

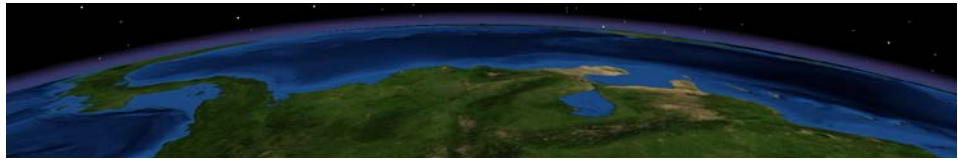
Supply Chain Relationships – Many of the agricultural opportunities in the Orinoquía depend on the development of equitable and cost-effective supply chains. This is especially true of industrial crops like oil palm and rubber. Making the most of Orinoquía agricultural opportunities will require development of supply chains that respond to the needs of every link in the chain.

Similarly, engaging micro-enterprises like artisans and local food producers in the value chain for tourism is critical to share the benefit from these activities through the destination communities.

With some public investment in an Extension Service, research and infrastructure, supply chain alternatives would increase autonomy for medium and small producers, which may prove to be more competitive.

Importance of Market Development Activities – Preliminary market development activities are key to the successful creation of new farms and businesses, especially in tourism. These include research on consumer markets, development of distribution relationships, and foundational marketing activities. Market and product/destination

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development are not sequential – they must happen at the same time and are mutually reinforcing.

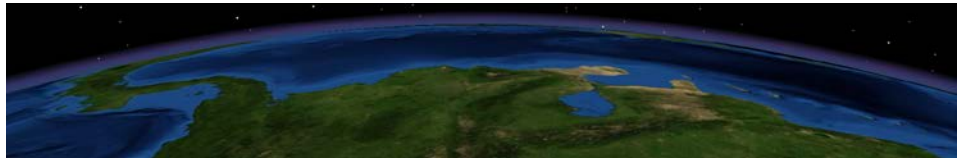
Environmental Sustainability – Issues of social and environmental sustainability should remain an ongoing discussion as enterprises and activities develop in the Orinoquía. Colombians are justly proud of the biodiversity in their country. Protecting the environment should be a crosscutting objective for future activities.

Attracting/Developing Labor and Expertise – Development of medium- and small-scale agricultural and tourism businesses is a key opportunity for attracting labor and expertise to a region that generally lacks those resources. This is especially true in the Altillanura and flooded savannahs.

The opportunity to own and manage a farm or business could attract motivated and entrepreneurial people from other parts of Colombia and provide opportunities for those displaced by conflict. Those small- and medium-scale farms and businesses would create stable, sustainable communities; while at the same time provide a larger pool of local labor for neighboring large-scale operations. Developing local expertise to satisfy the potential growth in labor demand will be important to sustained economic growth from these activities.

International Collaboration as Catalyst – The peace process opens the opportunity for Colombian institutions to work together and benefit from sharing their individual areas of strength. In many parts of the world, post-conflict/post-disaster collaboration is facilitated by outside organizations that bring technical expertise, experience with similar situations elsewhere, and credibility. The right outside organization can be a catalyst that brings local institutions and organizations together. The Orinoquía Initiative led by Purdue University and the associated Technical Committee shows the potential for an international collaboration to connect Colombian stakeholders for the future development of the region.

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8.1 Next Steps

Based on discussions with Colombian stakeholders, next steps include the following:

- Implement the agriculture and tourism pilot project proposals and reinforce agricultural and tourism planning capacity in the region.
- Promote the adoption and use of the analytical modeling tools developed by Purdue. Continue modeling activities for specific regions and incorporating policy analysis.
- Develop an Extension Service model/land-grant university concept for rural higher education that will educate producers and farmers on the use of the modeling tools that will build engagement opportunities among farmers and research-Extension personnel to communicate applied research results to help local producers improve agricultural production.
- Reinforce agricultural and tourism planning capacity in the region through additional training for national, departmental and municipal planning staff, and through joint research and engagement projects with Agrosavia, UNILLANOS, Unitropico (the International University Foundation of the American Tropics) and other Colombian institutions.
- Strengthen the capacity of primary, secondary and tertiary educational institutions in the Orinoquía region to respond to the urgent need for a trained workforce in the region.
- Increase water-management information in the area and develop land-use and water-management tools with stakeholder participation to resolve the development impasse in the Casanare and Arauca departments.



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Appendix 1

Case Study Example

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Identifying New Technologies in the Agricultural Systems of the Piedemonte

John H. Sanders and Jhon A. Carillo Rozo

May 21, 2018

Introduction

The Piedemonte has been the center of repeated migration from the Sierra. There has been a concentration of small (<40 ha) and medium farmers (40 to 100 ha). The plains of Meta (the Altillanura) has been an attraction for large scale beef producers historically and more recently (last 20 years) for large farmers and agro-industries producing sugar for ethanol, palm oil for diesel fuel, rubber, rice, corn and soybeans. There are also small and medium independent farmers in the Altillanura, who could also benefit from these innovations discussed here.

Rather than describing the systems of production the focus here is on identifying new technologies coming out of scientific research especially but not exclusively from Agrosavia (formerly CORPOICA). The second component is that this is not simply experiment station results but the technology is being introduced on farms in the Piedemonte. So the focus is on new technologies and farmer options whose introduction could be accelerated. This is not impact analysis calculating the benefits and costs of technologies already successfully introduced but a systematic evaluation of potential introduction leading to recommendations on facilitating that process.

Methodology

The first concern is the conceptual analysis. What are the characteristics of technologies for small and medium farmers in which they are expected to have a comparative advantage. To compare and contrast a wide range of activities the Piedemonte region is initially treated as if it were a farm. Then we gradually introduce more regional and farmer specificity to the model. For example, coffee is principally found very high up on poorer soils. Fruit production is concentrated in certain regions such as Ariari.

Conceptually small and medium farmers are expected to have a comparative advantage in activities that are very labor intensive in production and whose production operations are difficult to mechanize. In Colombia custom machine operations are widespread on small farms as the medium farms in the region can finance more of their own machinery stock by renting these services. For many activities such as fruit and coffee production substantial seasonal labor is required and the more labor intensive operations give an advantage to the small farmers.

This study is based on farm level data including production costs, labor and capital use, yields over the production cycle, and product prices. There is no substitute to asking farmers for these data. The samples were small, three to five farms for most activities but there were a large number of activities here. For a small farm in the Piedemonte with 3 ha of irrigated land and 15 ha of non-irrigated land there were 13 non-irrigated and 10 irrigated or potentially irrigated

enterprises identified and interviewed. Farmers could purchase 40 man days of labor each month.

The modeling was conducted using the linear program developed by Purdue University for use in the Orinoquía region of Colombia. This model maximizes income over a one year period using steady state parameters and constraints on the available on-farm and off-farm inputs. Since many of the activities in the Piedemonte are perennials, the steady state technique was employed. To reduce crop choices including perennials to a one year decision process each enterprise was reduced to a one ha unit. For example a perennial with a ten year life cycle would have one tenth of a ha for each year of the cycle. Then the model gives the optimum combination of enterprises.

Table 1. Enterprises Chosen for the Region

Enterprise	Ha.	Shadow prices
Irrg. Guayaba		-688
Irrg. Citrus	0.38	
Irrg. Cacao		-6986
Irrg. Oil Palm		--4492
Irrg. Pineapple	1.62	
Irrg. Caucho		-4903
Irrg. Cacay		39916
Irrg. Mangostino	0.85	
Irrg. Avocado		-1470
Nolr. Citrus	0.98	
Nolr. Cacao		-6561
Nolr. Oil Palm		-725
Nolr. Pineapple		-9366
Nolr. Fish	1.000	20891
Nolr. Caucho		-1.706E+4
Nolr. Cacay		28184.49
Nolr. Rambutan		-2.334E+4
Nolr. Mangostino		-3243
Nolr. Ganado Ceba	10.08	
Nolr. Coffee	1.94	
Nolr. Silage		-1.388E+4
Nolr. Dairy		-7260
Incomes	159,400,000 pesos	\$56,928 dollars

Source: Based on field data collected from February –March 2017 and in October 2017. Irrg. – Irrigated Nolr. – non-irrigated.

Exchange rate of 2,800 pesos/dollar)

This is a very high income but note that this is not an actual farmers' income but the choice of the most profitable activities for the Piedemonte region on this farm size. This is well beyond what farmers could manage with all the complicated technologies and markets for fruits and the high cash requirements involved in fattening operations. Moreover, gross margin as a measure of income does not include the pay to family labor, implicit rent to land or the return and compensation to the farmer for risk and for his opportunity costs. Now we will start making this more realistic by introducing regional and farm size factors. We will discuss later how to get more accurate estimates of yields over time given the riskiness of agriculture.

Note the importance of fruits and coffee in the region. Fattening of beef cattle (ceba) and fish were both very important activities. We constrained fish production to only 2 ha. Note that there are 1,200 fish pond producers in the Meta region (Carlos Alberto Medina, CEO of AgroFoods, Oct 2017 conversation). Fattening or finishing beef is also very important in this higher rainfall region with better soils. Most of the fattening for the Orinoquia is done in the Piedemonte (Luis Eduardo Arias, Director, Comite de Ganaderos de Meta, Conversation, Oct. 2015).

Next we move towards regionalization in Table 2 as there is substantial regional variability in topography and soil in the Piedemonte. First coffee is eliminated as we only found it in the higher areas with poorer soils. Secondly, fattening is associated more with medium size farmers as it requires substantial capital to buy the animals at auction usually and to set up good feeding practices.

Table 2 Shift to Fruits in the Piedemonte

Enterprise	Ha.	Shadow Prices
Irrg. Guayaba		*-335
Irrg. Citrus	0.31	
Irrg. Cacao		-7324
Irrg. Oil Palm		-5145
Irrg. Pineapple	1.69	
Irrg. Caucho		-5370
Irrg. Cacay		37331
Irrg. Mangostino	1.00	
Irrg. Avocado		-5475
Nolr. Citrus	1.34	
Nolr. Cacao		-5911
Nolr. Oil Palm	2.60	
Nolr. Pineapple		-8131
Nolr. Fish	2.000	

Nolr. Caucho		*-1.386E+4
Nolr. Cacay		25236
Nolr. Rambutan		*-2.829E+4
Nolr. Mangostino		-3047
Nolr. Ganado Ceba		25
Nolr. Coffee		849
Nolr. Silage		*-1.330E+4
Nolr. Dairy		-7040
Incomes	158,040,000 pesos	\$56,443 dollars

Source: Based on field data collected from February –March 2017 and in October 2017. Irrg. – Irrigated Nolr. – non-irrigated. At the exchange rate of 2,800 pesos/dollar

Incomes are decreased but very little by the exclusion of coffee and fattening. But the farmer becomes dependent on producing many fruit and other activities. We have not seen this much diversification in our total of nine weeks interviewing farmers. We return to the issue of labor constraints and that appears to be the reason that only 5.9 ha. were produced of a possible 15 ha. of unirrigated land. The shadow prices or in the case of labor the additional costs of purchasing an additional unit of labor in April and July are 505,000 pesos and 499,000 per manday. respectively. More discussion later on shadow prices for the activities.

Historically, most small farmers in the Piedemonte have been subsistence farmers with only local sale and home use. These subsistence activities included low productivity milk production (5 to 6 liters of milk/cow/day), sugar cane for panela, cassava, plantains and subsistence production of maize. Most had and still have a "pan coger" or home garden with a wide range of products on a small area. With the improvements in transportation to Bogota, the truce with FARC, and the increased demand from Bogota and urban Colombia for higher quality diets, especially more meats, milk, cheese, fruits and vegetables, this is changing to more specialization on one or two commodities for sale to Bogota.

Now there is a body of scientific evidence and practice on high productivity fruit production. There has been increasing fruit produced and marketed to Bogota from the Piedemonte region including pineapple, oranges, guava, papaya, and maracuyá. We show here the high profitability of various fruit production activities and compare them with other Piedemonte activities such as traditional dairy. There are several exotic fruits being grown in Colombia with potential for increasing domestic and export consumption including Rambutan and Mangostino

(Asia) and Sacha Insa (Peru) (Dr. Javier Orduz, fruit specialist, La Libertad Station, CORPOICA, Villavicencio, Oct 2015) .

Here besides the irrigated pineapple, citrus, and mangostino become important activities. Also oil palm enters and fish stays at 2 ha.¹

The coffee was principally found in the poor soil of the higher areas. But coffee also has the same characteristics of high labor requirements and difficulty to mechanize the production operations as the fruits. The demand for specialty coffees appears to be still increasing in the world. So let's look at the alternatives for this poorer soil on area higher up in the hills where coffee was found. The farm size here is shifted to zero irrigated and 10 ha of non-irrigated land with 60 and then 40 man days per month of temporary labor available to farmers.

In the highlands coffee dominates. In citrus the farmers had planted three types, Mandarin, Vallencia and Tangelo. Tangelo's price was over four times the price of the other two. If all the citrus were Tangelo, then coffee still dominates but citrus increases from negligible at 0.05 ha to 1.4 ha with the labor constraint of 60 man days per month.

With the availability of 60 man days per month labor is never a pressing constraint for all coffee but becomes so at 40 man days per month availability as in Table 3 below. Getting labor high up in the hills with often poor transportation connection is more difficult. Note that even with this substantial increase in prices for citrus there is no change in area of the two crops but shadow prices change. In October and then November labor costs become very constraining. So this indicates the pressure for obtaining labor seasonally in the critical months.²

Returning to Tables 1-3 the negative values on the shadow prices on the outputs indicate the loss of income if another ha of this activity were forced into the output mix. The positive value occur only where a ceiling on area was imposed and gives the income increase from raising this ceiling by one ha.

Dairy never entered as an activity here demonstrating the low returns and basic subsistence nature of this enterprise even with 50% of the milk being used for milk products of higher value and sold in local village markets, ie cheese and arequipe. Yields were very low at 5 to 6 liters/cow/day and prices for fresh milk were discounted after lab analysis³ by the major milk

¹ There was an upper bound put on fish as this was a very large initial investment. Fruit production also required substantial expenditures for chemical controls and fertilization. We expect that farmers will shift from milk production or just diversify but maintain their dairy operation. But the dairy operation gives them a source of potential capital investment for the fruit operation by selling off their older cows.

² Notice that before hiring labor the farmer uses his family labor.

³ Lab analysis results were not reported to farms in San Juan de Arama but were used as a justification for price discounts.

producers. In the informal markets these same prices prevailed. In summary, the shift to tangelos did substantially increase farm incomes but did not change the crop mix at the labor availability of 40 mandays per month.

Table 3. Enterprise Choice in Highlands

Enterprise	Crop Area (ha)		Income total		Labor Available/man-days per month	Shadow price per man day (1000 pesos)	
	Eq 1	Eq 2	Eq 1	Eq 2		Eq 1	Eq.2
Coffee	7.4	7.4			40 in Oct	505	157
Citrus	1		50,640,000 pesos \$18,086 dollars		40 in Nov	60	727
Tangelo		1	71,935,000 pesos \$25,691 dollars				

Source: Based on field data collected from February –March 2017 and in October 2017.

When we only include activities in the fruit regions such as Ariari, we first get the same results as in Table 2. Here we are returning to a farm of two irrigated ha and 15 unirrigated ha. with 40 man days of temporary labor available.

Besides the fruits we first run the model with fish and palm oil. Then in the second equation we take out palm oil and fish. This changes results in an expansion of the non-irrigated fruits but not very much as the labor constraint quickly becomes pressing. But there is a substantial income decline. The next step would be to look at 50 mandays available as of the potential 15 non-irrigated ha available only 4.8 was used in the all fruit case. Clearly the labor supply is a pressing constraint as indicated by the area cultivated and the shadow price in both cases.

Table 4. Enterprise Choices for the Fruit Producing Region (Ariari)

Enterprise	Ha of Eq. 1	Ha of Eq. 2	Shadow prices for Labor (1000 pesos/manday)	
			Eq. 1	Eq. 2
Irrg.Citrus			July 439	July 435
Irrg. Cacao				
Irrg. OilPalm				
Irrg. Pineapple	2.0	2		
Irrg.Caucho				
Irrg. Cacay				
Irrg. Mangostino				
Irrg. Avocado				
Nolr. Citrus	1.6	2.5		
Nolr. Cacao				
Nolr. Oil Palm	2.6			
Nolr. Pineapple				
Nolr. Fish	2.0			
Nolr. Caucho				
Nolr. Cacay				
Nolr. Rambutan				
Nolr. Mangostino	1.6	2.3		
Nolr. Ganado Ceba				
Nolr. Coffee				
Nolr. Silage				
Nolr. Dairy				
Incomes	158,040,000 pesos	88,841,337 pesos		
	\$56,443 dollars	\$31,729 dollars		

Source: Based on field data collected from February –March 2017 and in October 2017.

Finally we consider the mid-sized farmers in the Piedemonte. The medium farm size is defined as a farm size with zero ha of irrigation and 50 ha of non-irrigated area. Labor use is zero permanent labor and 40 man days per month. We initially used a fairly high productivity of 1.8 animals weighted per ha. Since the spread sheet is linked, it is a very simple activity to change

this productivity measure and then substitute the new line in the Commodity Yields of the excel spread sheet for GAMS (Piedemonte20171122). The result is the dominance of the fattening activity at 46 ha with the remaining four ha in Mangostino and citrus. If substantial labor is added at 120 man days per ha plus two permanent workers the fattening operation is reduced to 40 ha and fruits increased to almost 10 ha. Incomes go up from \$32,483 dollars to \$41,457 with this shift to more fruit production even with the much larger labor expenditures. Finally if we allow in both cacay and oil palm with even higher labor expenditures of four permanent laborers and again 120 man days available per month incomes are further increased to \$56,932.

In the field medium sized farmers specialized in fattening were not observed using substantial hired labor to expand into fruit production. Fruit production remains a small farmer activity. Oil palm production requires reasonable proximity to the processing plant. So the first run in Table 5 appears to be most appropriate for the region and is supported by the widespread Piedemonte fattening operations supporting cattle production in the entire Orinoquia region. The new technology of most interest seems to be the silage to feed during the dry season and in the milk production activities to support higher levels of productivity.

Table 5. Activities of the Middle Sized Firm in the Piedemont

Enterprise	Ha.	Shadow Price
Nolr. Citrus	1.584	.
Nolr. Cacao	.	-2838.053
Nolr. Pineapple	.	-823.891
Nolr. Fish	.	38423.253
Nolr. Caucho	.	-76.782
Nolr. Cacay	.	473.574
Nolr. Rambutan	.	-2.389E+4
Nolr. Mangostino	1.882	.
Nolr. Ganado Ceba	46.534	.
Nolr. Coffee	.	2809.58
Nolr. Silage	.	-1.130E+4
Nolr. Dairy	.	-3427.875
Nolr. Dairy adv	.	-2965.005
Incomes	90,954,000 pesos	\$32,483 dollars

Source: Based on field data collected from February –March 2017, October and November 2017. Irrg. – Irrigated Nolr. – Non-Irrigated. Exchange rate of 2,800 pesos/dollar

Income Estimates for the Above Enterprise Choices

Note that the income estimates in Tables 1-4 appear to be very high. This is the problem of estimating future incomes for perennials in regions with substantial yield variability due to high rainfall and the lack of frosts to kill off insects and other organisms. More systematic yield calculations over time would estimate the value and probability of yield shocks and incorporate this into the estimates of yields over time. We did some of this adjustment for coffee over time and coffee still stays in the crop mix so maybe some of our other estimates are also reasonable. In any event the relative profitability is more what we are interested in as the absolute profitability is probably indicated by farmers staying in the activity. If they were losing money, they would get out of the enterprise or at least scale back input use until product prices improve as the most inefficient producers leave production.

Besides over estimates of yields we expect underestimates of long run costs as farmers need to respond to soil fertility depletion and the build-up of pests over time. So a concentration on yields over time focusing upon yield collapses and on long run costs would be expected to handle the over estimates of yields here.⁴

Price Risks from Market Saturation and Monopsony/Oligopsony:

In Colombian agriculture most activities experience cyclical prices and profitability. In annual activities this process works more rapidly than with perennials as there is a delay with tree or bush production before it reaches maximum yields and a reticence to cut down the trees/bushes. The general response to falling prices of perennials is to reduce input use and wait if the farmers' land availability allows him to do this.

Since farmers must acquire technical and marketing knowledge to produce and sell for the Bogota market, the common response to the expectation that with the good prices for fruits supply will grow faster than demand, is to anticipate the need for diversification. For example, farmers producing guava intensively for the Bogota market were observed initiating production of avocado, which takes three to five years to start production.

A second major problem is the price fixing and efforts by the wholesalers to close alternative markets to the farmers of the Piedemonte. Wholesalers sell to the ambulant merchants selling small quantities to the low income sector and to the small neighborhood stores selling to the middle class and often providing credit to regular customers. The supermarkets sell imported and domestic products to the wealthier and require regular supplies and good quality control. An alternative market for small farmers especially in associations is to sell to the neighborhood stores but that would require transportation and previous arrangements as these neighborhood

⁴ There is also a tendency in Colombian agronomic recommendation to maximize yields rather than the economic returns. Farmers interviewed then repeat these high input recommendations until later in the interviews when they admit to reducing them. In the last year CORPOICA has added 8 economists to their professional staff.

stores would not buy truckloads. However, Corabastos wholesalers market can and have threatened to cut off these small stores from access to Corabastos for using other sources.

Health concerns:

The market demand for very clean fruit with no insect or disease damage encourages high and indiscriminate use of chemicals with residual effects left on the fruit (Dr. Javier Orduz, fruit specialist, La Libertad, CORPOICA, discussion, Oct 2017). Hence, the research push in CORPOICA for biological controls and their increasing use in the Piedemonte. But there also appears to be a need for more public intervention to insure public health.

Conclusions:

So there is already a class of small and medium farmers in the Piedemonte responding to the application of the increased scientific knowledge and practices available from Agrosavia and to the price incentives from the demands for higher quality foods in the major urban areas. Except for those activities potentially leading to increased exports as avocado or guava juice, this process of declining prices over time will occur as long as the supply increases from this group of better producers taking advantage of the higher prices continues to exceed the demand growth arising from higher incomes in urban Colombia. This indicates substantial opportunities for public policy to accelerate this process achieving both output and income distribution goals.

There is another phenomenon in this marketing growth of the natural tendency of few buyers and many sellers in the Piedemonte and elsewhere to lead to the price fixing of monopsonies/oligopsonies. Responding to this for Piedemonte farms requires finding alternatives markets outside the control of these CORABASTOS wholesalers and/or obtaining more bargaining power through increased quality control and larger sales volume in farmers' associations.⁵

A response to low prices from the oligopoly of the two major dairy buyers (Recreo and Alqueria) besides selling to informal local markets is to make and sell locally milk products, cheese, yogurt, kumis (egg nog) and "arequipe"(traditional dessert from milk). But for this to affect incomes substantially associations/companies would need to develop quality products, which could be widely sold in Colombia.

Systematic cheese production with brand names, quality control, packaging and advertising could potentially become profitable activities benefitting small and medium farmers with wider sales outside the region. But these cheese producers would need to register (health practice certification) to enter formal markets, assure healthy production and processing conditions as well as the marketing activities recommended above. Farmers' associations with improved

⁵ Many Colombians are very pessimistic about the potential of associations. Associations to get member collaboration require trust and transparency from their management.

quality control and increased bargaining power could negotiate with the few buyers, the wholesalers, or sell to the larger number of neighborhood stores and supermarkets.

Since much of the finishing or fattening from the entire Orinoquia is done in the Piedemonte it is important to identify technology for this sector. We expect that silage production from various crops to be an increasing important activity for higher productivity dairy producers and fattening operations, both medium farm activities. However, silage production did not enter as a profitable activity for either small or medium farmers by itself but was associated with a dairy or a fattening operation.