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CPP_CS18-5

Identifying New Technologies in the Agricultural Systems of the Piedemonte

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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. Therefore, 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 three 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).

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 Orinoquía is done in the Piedemonte (Luis Eduardo Arias, Director, Comité 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.

Incomes are decreased but very little by the exclusion of coffee and fattening. However, the farmer becomes dependent on producing many fruit and other activities. We have not seen this much diversification in our total of ten 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 man-day, respectively. More discussion later on the interpretation of the shadow prices for the activities.

Table 1. Enterprises chosen for the region

Enterprise	Ha.	Shadow prices
Irrg.Guava		-688
Irrg.Citrus	0.38	
Irrg. Cacao		-6986
Irrg. Oil Palm		4492
Irrg. Pineapple	1.62	
Irrg.Rubber		-4903
Irrg. Cacay		39916
Irrg. Mangostino	0.85	
Irrg. Avocado		-1470
NoIr. Citrus	0.98	
NoIr. Cacao		-6561
NoIr. Oil Palm		-725
NoIr. Pineapple		-9366
NoIr. Fish	1	20891
NoIr. Rubber		-1.71E+04
NoIr. Cacay		28184.49
NoIr. Rambutan		-2.33E+04
NoIr. Mangostino		-3243
NoIr. Cattle Ceba	10.08	
NoIr. Coffee	1.94	
NoIr. Silage		-1.39E+04
NoIr. 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; NoIr. – Non-irrigated. Exchange rate of 2,800 pesos/dollar).

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 Bogotá, the peace agreement with FARC, and the increased demand from Bogotá 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 Bogotá.

Table 2. Shift to Fruits in the Piedemonte

Enterprise	Ha.	Shadow Prices
Irrg.Guava		*-335
Irrg.Citrus	0.31	
Irrg. Cacao		-7324
Irrg. Oil Palm		-5145
Irrg. Pineapple	1.69	
Irrg.Rubber		-5370
Irrg. Cacay		37331
Irrg. Mangostino	1	
Irrg. Avocado		-5475
NoIr. Citrus	1.34	
NoIr. Cacao		-5911
NoIr. Oil Palm	2.6	
NoIr. Pineapple		-8131
NoIr. Fish	2	
NoIr. Rubber		*-1.386E+4
NoIr. Cacay		25236
NoIr. Rambutan		*-2.829E+4
NoIr. Mangostino		-3047
NoIr. Cattle Ceba		25
NoIr. Coffee		849
NoIr. Silage		*-1.330E+4
NoIr. 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 NoIr. – Non-irrigated. At the exchange rate of 2,800 pesos/dollar.

Now there is a body of scientific evidence and practice on high productivity fruit production. There has been increasing fruit produced and marketed to Bogotá 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 (both from 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. However, 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 us 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 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. Therefore, 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 occurs 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, i.e., cheese and arequipe (dulce de leche). Yields were very low at 5 to 6 liters/cow/day and the major milk producers discounted prices for fresh milk after lab analysis[3] in the informal markets. In summary, the shift to tangelos did substantially increase farm incomes but did not change the crop mix at the labor availability of 40 man-days per month.

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

[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. The dairy operation gives them a source of potential capital for initiating 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.

Table 3. Enterprise Choice in the Highlands of the Piedemonte

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
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.

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 change results in an expansion of the non-irrigated fruits but not very much as the labor constraint quickly becomes pressing. Nevertheless, there is a substantial income decline. The next step would be to look at 50 man-days 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.

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 as the hiring maximum. We initially used a high productivity of 1.8 animals per ha. Since the spreadsheet is linked, it is a very simple activity to change this productivity measure. The result is the dominance of the fattening activity at 46.5 ha with the remaining 3.5 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 but with much larger labor expenditures. Finally, if both cacay and oil palm are crop choices and there are even higher-labor expenditures of 4 permanent laborers and 120 man-days are 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 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	2		
Irrg.Rubber				
Irrg. Cacay				
Irrg. Mangostino				
Irrg. Avocado				
NoIr. Citrus	1.6	2.5		
NoIr. Cacao				
NoIr. Oil Palm	2.6			
NoIr. Pineapple				
NoIr. Fish	2			
NoIr. Rubber				
NoIr. Cacay				
NoIr. Rambutan				
NoIr. Mangostino	1.6	2.3		
NoIr. Cattle Ceba				
NoIr. Coffee				
NoIr. Silage				
NoIr. 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.

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 farmers staying in the activity probably indicate the absolute profitability. 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.

Table 5. Activities of the Middle-Sized Firm in the Piedemonte

Enterprise	Ha.	Shadow Price
NoIr. Citrus	1.6	
NoIr. Cacao		-2838053
NoIr. Pineapple		-823891
NoIr. Fish		38423253
NoIr. Rubber		-76782
NoIr. Cacay		473574
NoIr. Rambutan		-2.39E+04
NoIr. Mangostino	1.9	
NoIr. Cattle Ceba	46.5	
NoIr. Coffee		280958
NoIr. Silage		-1.13E+04
NoIr. Dairy		-3427875
NoIr. Dairy adv		-2965005
Incomes	90,954,000 pesos	$32,483 dollars

Source: Based on field data collected from February –March 2017, October and November2017. Irrg. – Irrigated NoIr. – Non-Irrigated. Exchange rate of 2,800 pesos/dollar.

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 incomes 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 Bogotá 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 Bogotá market were observed initiating production of avocado, which takes three to five years to start production.

[4] There is also a tendency in Colombian agronomic recommendation to maximize yields rather than economic returns. Farmers interviewed then repeat these high input recommendations until later in the interviews when they admit to reducing them. In 2016-17 CORPOICA has added 8 economists to their professional staff.

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. 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 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 often 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 Corpoica (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 milk products, cheese, yogurt, kumis (egg nog) and "arequipe" (traditional dessert from milk also known as dulce de leche). 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

[5] Bargaining power in input and product markets is critical for small and medium sized farmers. Farmers' associations are one of the best ways to obtain this bargaining power by selling (buying) in larger quantities and controlling better for quality and timing of delivery However, associations need to obtain member collaboration by creating trust and transparency in the management.

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 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 in Bogota.

Since much of the finishing or fattening from the entire Orinoquía 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. In future runs we will consider fattening operations with and without silage production or purchase.