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CGIAR CCAFS

Info Note

Cassava starch content and its relationship with rainfall

Analysis of a starch content database in Colombia

By Patricia Moreno and Sharon Gourdji

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Key messages

- In addition to human and animal consumption, cassava has great potential for industrial use through starch extraction. Cassava starch is used in the food-processing, paper, glue, textiles, and pharmaceutical industries. (Alarcón and Dufour 2012).
- A decrease in cassava starch content creates less starch yield with more residues and water consumption during processing (Maieves, et al. 2011). For the case study with the "Almidones de Sucre" factory, this decrease in starch content incurs a lower payment to the farmers as a function of fresh root weight.
- This study evaluates the relationship between the fluctuations of starch content in cassava and the seasonal behavior of rainfall.
- A statistical model was developed relating precipitation variables with the starch content of cassava deliveries to the processing factory "Almidones de Sucre" in the Caribbean coast of Colombia.
- This model shows that there is a relationship between the decrease of cassava starch content and high rainfall during the last month before harvest. Similarly, the onset of precipitation after a dry period during the last 3 months before harvest creates lower starch contents.

According to the statistics in the AGRONET database (2013), more than 50% of the national area and production of cassava occurs in the departments in the North Coast of Colombia. The departments included in this study, Cordoba and Sucre (Figure 1), have the second and fourth highest sown area of this crop, respectively, at the national level.

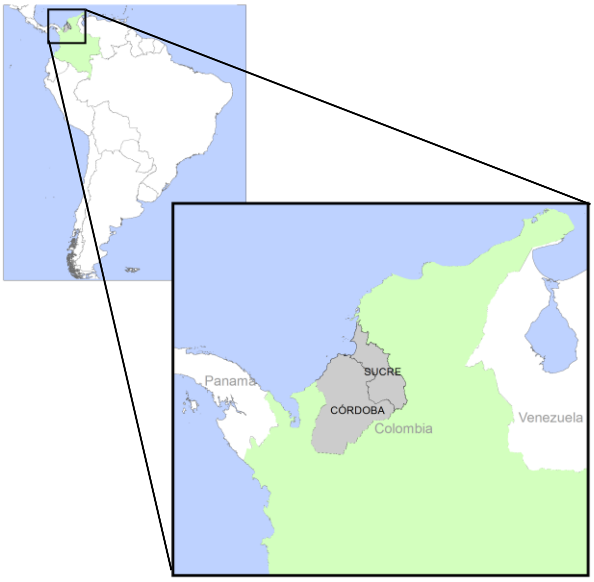

Figure 1 Location of the study region: Cordoba and Sucre departments.

In addition to direct human and animal consumption of cassava roots, cassava has great potential in industry through starch extraction (Figure 2). However, most cassava production takes place during certain times of the year corresponding to seasonal rainfall patterns which define the sowing dates for the crop (Alarcón and Dufour 2012). These production peaks create shortages of raw material for industry and the closure of processing factories such as "Almidones de Sucre" for some months of the year (Aguilera 2012). On the other hand, losses in starch quality are related to environmental conditions prior to harvest, where the onset of rains after a period of water stress has apparently causes a reduction in starch content and paste (Sriroth, et al. (2001)). Hence, this study seeks to evaluate the relationship between starch content and the seasonal behavior of precipitation during the growing season of the crop.

Figure 2 (a) Cassava harvest in Cordoba, Colombia[1]; **(b)** weighing cassava at the "Almidones de Sucre (AdS)" plant to estimate starch content; **(c)** cassava cutting as the initial process in the AdS factory.

Starch content in entries to the factory "Almidones de Sucre (AdS)" from 2009 to 2013 shows a seasonal behavior where a decrease in starch has a lagged correlation with dry months or low rainfall. After the driest months of the year in December, January and February, and during the months of rainfall onset, starch content decreases (Figure 4 (a) and (b)).

Using monthly climate data from weather stations maintained by the Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM), we sought to establish a relationship between fluctuations in cassava starch content and precipitation during the crop cycle for entries to the plant originating in the departments of Sucre and Cordoba.

Data

The sites of origin of the root entries to the plant were located with the help of technicians from the AdS factory; in this way, 75 locations were identified for the 3641 registries in the database. Nearby weather stations were selected within a radius of 15 km around each location of origin within the AdS database (Figure 3). Monthly precipitation was then interpolated from the station locations to the cultivation sites using an inverse distance weighting (IDW) algorithm (Pebesma and Graeler 2015).

For each one of the 3641 registries in the AdS database, the harvest date was estimated as 5 days before the entry to the factory, taking into account the short post-harvest duration of the roots and that the company returns orders with rotten material. Additionally, the sowing dates were estimated as 10 months prior to the harvest dates, considering the typical growing season duration.

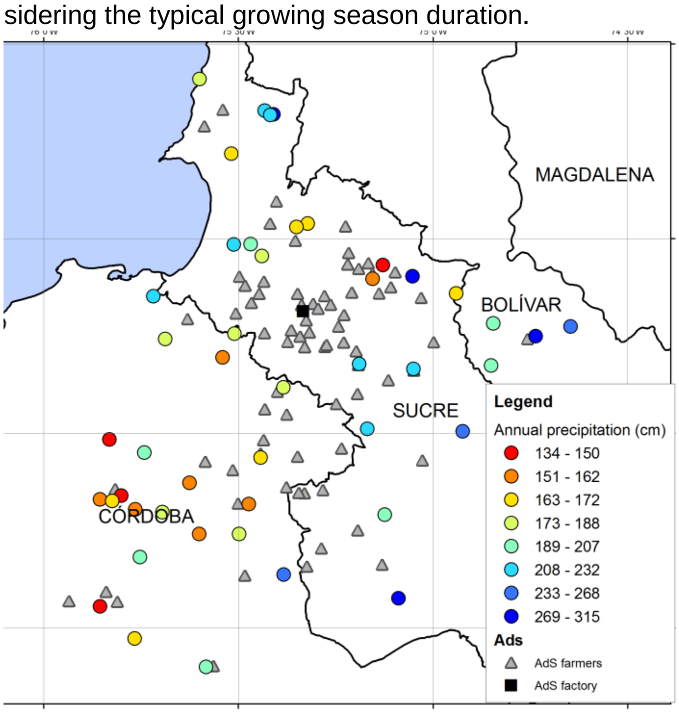

Figure 3 Location of the sites of origin of the cassava entries to AdS and the weather stations used for the analysis. The colors show the annual average rainfall for 2009-2010 for those stations with complete data over this period.

Statistical model

Based on the estimated sowing and harvest dates for each entry to AdS, we estimated the following climatic variables which could potentially explain the variability of the starch content in cassava entries to the factory:

- **Prec.tot:** Total rainfall during the growing season of the crop (from sowing to harvest dates).
- **Prec.last:** Precipitation of the last month of the growing season of the crop.
- **Prec.ind:** Index which compares total precipitation in the last month before harvest with precipitation in the last 3 months of the growing season.

[1] This research was performed as part of the collaboration between the Colombian Ministry of Agriculture and Rural Development (MADR) and CIAT.

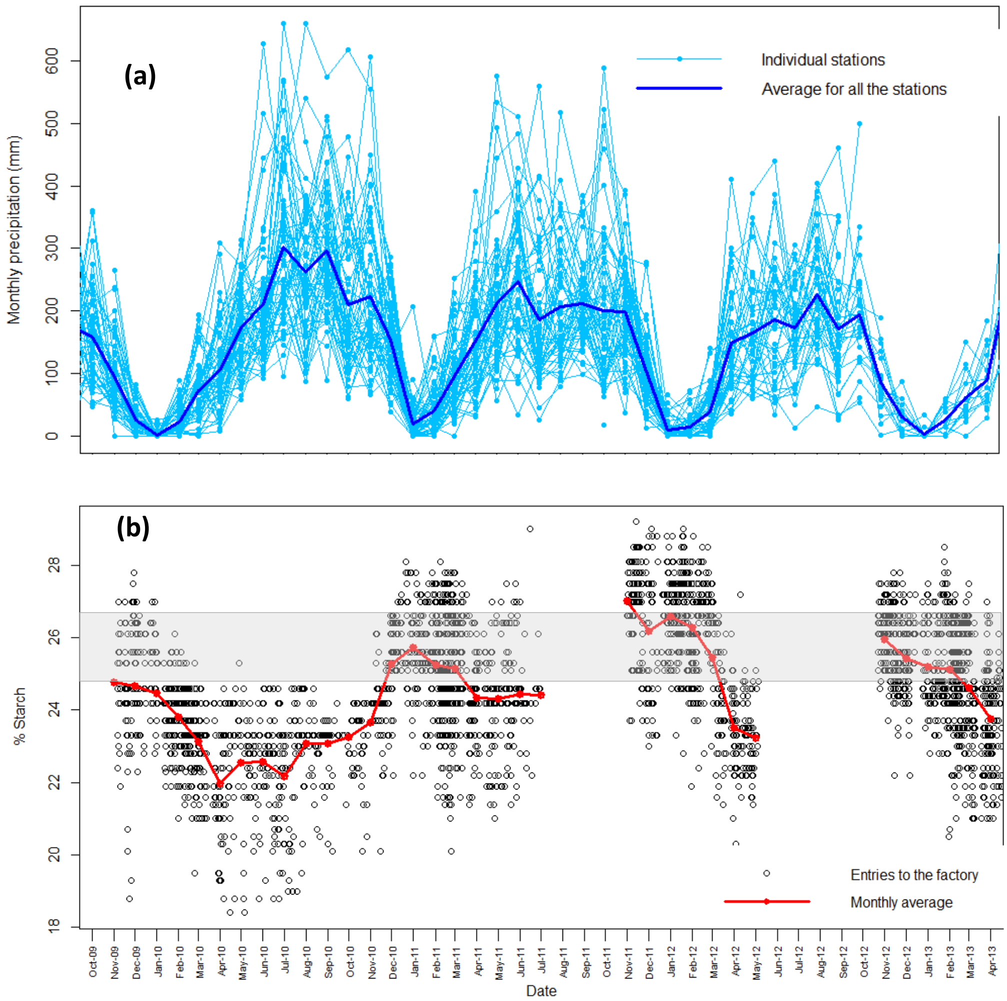

Figure 4 (a) Monthly precipitation (mm) of the weather stations used for the analysis. (b) Historical starch content as percentage of fresh weight at the date of entry to the AdS factory. The grey square shows the threshold of starch content with a standard price of 180 Colombian pesos/ kg for 2013.

For the calculation of all precipitation variables, we assumed a uniform distribution of monthly precipitation for each day of the month. Given that all climatic variables were defined at the monthly or coarser timescales, we believe that this assumption did not affect the quality of the calculated variables.

These climatic variables were chosen as potentially explanatory of cassava starch content, as corroborated by previous literature. For example, Howeler (2007) mentioned the negative correlation between starch content and precipitation during the month prior to harvest in Thailand. Ceballos et al. (2007) and CIAT (1992) argue that when the rains start, the cassava plant restarts its development by extracting the energy accumulated in the roots; as a consequence, the dry matter as well as the starch content of the roots begins to fall. Likewise, Sriroth *et al.*, (2000) mention the importance of environmental conditions immediately before harvest; the onset of rainfall after a long period of water stress creates starch with different characteristics (e.g. root yield, starch content, cyanide content, granule size, paste viscosity, paste temperature, among others).

Next, we related the climatic variables to the starch content of the roots in a multiple regression model including all entries to the AdS factory using the formula:

$$\%\boldsymbol{starch} = \boldsymbol{prec.tot} + \boldsymbol{prec.tot^2} + \boldsymbol{prec.ind} + \boldsymbol{prec.ind^2} + \boldsymbol{prec.last} + \boldsymbol{prec.last^2} \quad (1)$$

Linear as well as quadratic factors were included for each climate variable, considering the potential existence of non-linear relationships between precipitation and the accumulation of starch in cassava roots.

Results and conclusions

Model results show an R^2 of 0.26, indicating that the climate variables are explaining 26% of the starch variability for the entries to the factory. Figure 5 shows that the model does not capture extreme values, likely due to other non-climatic factors related with crop management (e.g. fertilization that may increase the starch percentage). However, each variable is highly significant individually in the model (Table 1).

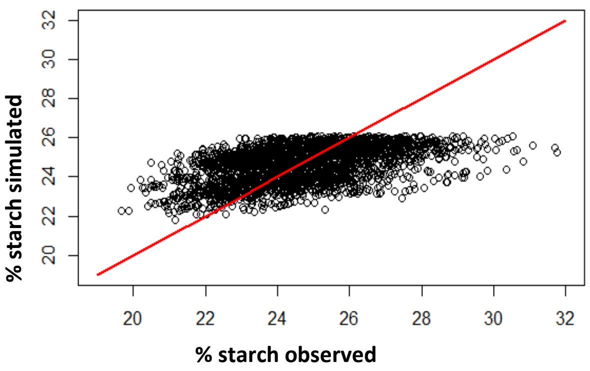

Figure 5 Observed vs. Simulated starch percentage

The estimated influence of each climate variable on the starch content is observed in Figure 6. An increase in total seasonal rainfall (prec.tot) is beneficial for increasing starch content up until about 1800 to 2000 mm. In the last month of the crop prior to harvest (prec.last), high precipitation decreases the starch content. Similarly, the higher the ratio of precipitation in the last month relative to the 3 months before harvest (prec.ind), the lower the starch content. It is important to clarify that the model should not be used outside the range of the data used for its creation. For example, one should not use the model to evaluate the effect of the total growing season and last month rainfall with values greater than 2200 mm and 200 mm, respectively.

Table 1 Estimated values, standard error and levels of significance for the variables included in the model ('***' =p<0.001, '**' =p< 0.01, '*' = p< 0.05, '.' = p< 0.1).

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	2.00E+01	3.80E-01	52.705	< 2e-16	***
prec.tot	6.15E-03	4.97E-04	12.37	< 2e-16	***
eval(prec.tot^2)	-1.56E-06	1.62E-07	-9.636	< 2e-16	***
prec.ind	-1.52E+00	5.93E-01	-2.558	0.0106	*
eval(prec.ind^2)	-1.24E+00	6.65E-01	-1.858	0.0633	.
prec.last	5.27E-03	1.33E-03	3.967	7.41E-05	***
eval(prec.last^2)	-3.12E-05	4.13E-06	-7.561	5.06E-14	***

These results can be explained as a typical situation for the cassava crop where after a period of water stress, the increased availability of water creates a high percentage of sprouting as a result of the translocation of photo-assimilates from the roots to the top; this translocation generates a decrease in both the dry matter and the starch content of the roots (Ceballos, et al. 2007). The model results also are consistent with the low starch contents reported in extended harvest trials in the north coast of Colombia after a period of increased rainfall before harvest. (These trials were done in consortia with farmers, CLAYUCA, i.e. the Latin American and Caribbean consortium to support cassava research and development, and the University of Cordoba (Universidad de Córdoba)[2]). Similar findings are reported by Da et al. (2008) for small-scale cassava starch processing in North Vietnam, where lower values of starch were found during the end of the processing season when the rainy period started. Additionally, Gu *et al*., (2013) reference the negative correlation between the dry matter content of the roots (of which 70-90% is starch) with precipitation during the three months before harvesting.

In order to help explain more of the variability in starch content, we also did sensitivity tests including fixed effects in the statistical model in order to help capture factors such as the physical and chemical properties of the soil and management (e.g. pest and disease control, fertilization) which may vary by farm or location. For example, Benesi *et al.* (2004) concluded that the location of the farm has the principal contribution in explaining the variability of cassava starch content. A test with fixed effects by farm origin of entries to the factory increased the R^2 of the model to 0.45; however, this model did not substantially change the estimated relationships between climate variables and starch content. For that reason, the results of this sensitivity test are not shown here.

We also initially considered the analysis of stress conditions in the first month after planting, given that previous studies have found a greater reduction in starch content for plants with water stress at the beginning of the growing season in contrast to the plants under water stress close to harvest (Sriroth et al., 2000; Santisopasri, et al., 2001). However, in this case with the available data, we did not find a clear relationship between precipitation in the first month after sowing and the final starch content. This could be due to the uncertainty in sowing dates, given that we assumed exactly 10 months before harvest date for all entries to the plant.

This study helped us to evaluate the importance of rainfall on cassava starch content at harvest considering the potential that cassava has for industrial use. In this way, it is important to consider environmental conditions at the projected harvest date in order to avoid a decrease in starch content. This is a challenge for farmers that need to balance harvests before the onset of the rainy season with the need to avoid long storage times of planting sticks for the next sowing when the rains arrive again.

In future work, it could be beneficial to have more data from the weather stations at a daily timescale in order to be able to analyze the relationship between rainfall and starch content at the sub-monthly scale closer to harvest time.

Further Reading

- "*El caso de la yuca: Pequeños agricultores, grandes investigadores*"- See more at: http://www.aclimatecolombia.org/el-caso-de-la-yuca-pequenos-agricultores-grandes-investigadores/#sthash.hhBZnAw1.dpuf

[2] This research is part of the same Project that funds the study of the database from "*Almidones de Sucre*" as part of the agreement with the Ministry of Agriculture and Rural Development (MADR)

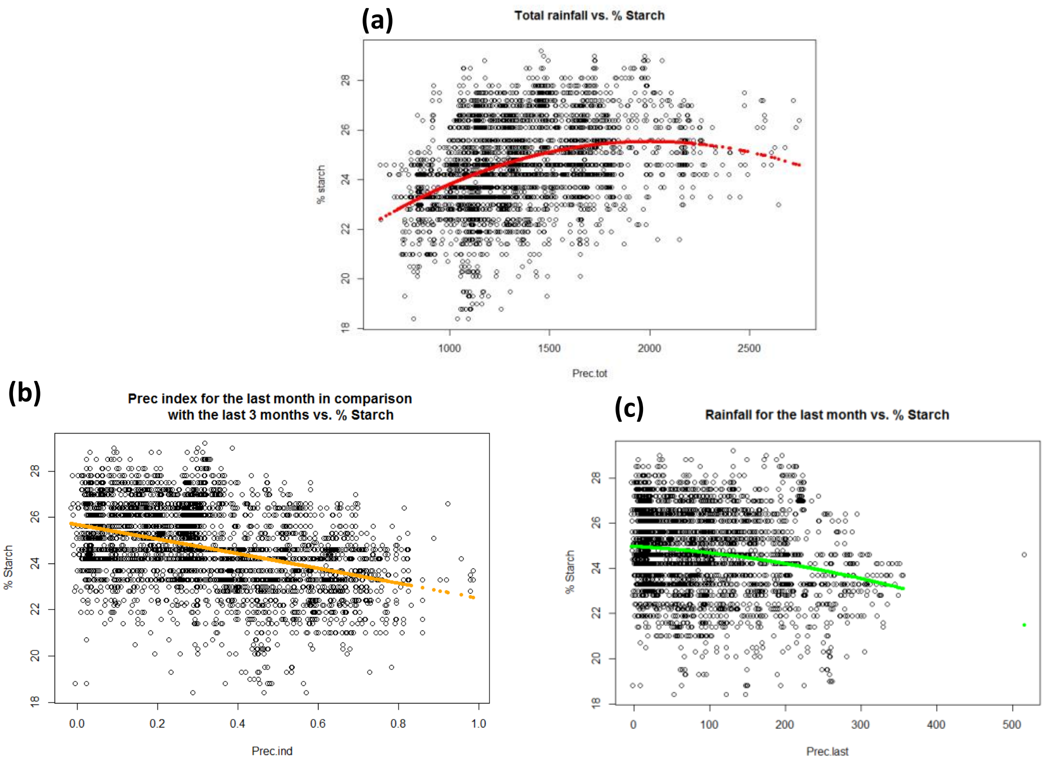

Figure 6 Estimated influence of each climatic variable considered in the model on cassava starch content **(a)** Total rainfall (prec.tot), **(b)** Precipitation index (prec.ind)**, (c)** Rainfall for the last month of the growing season (prec.last).

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Patricia Moreno *(l.p.moreno@cgiar.org) is a researcher with focus on cassava modeling of the climate and crop modeling team on CIAT within the Decision and Policy Analysis Area (DAPA).*

Sharon Gourdji *(s.m.gourdji@cgiar.org) is the coordinator of the climate and crop modeling team on CIAT within the Decision and Policy Analysis Area (DAPA).*

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