March, 2015

IST616A

Annotated Bibliography 1-
Growing Theobroma Cacao

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1. Motamayor, J. C., Risterucci, A. M., Lopez, P. X. A., Ortiz, C. X. F., Moreno, A., & Lanaud, C. (2002). Cacao domestication I: the origin of the cacao cultivated by the Mayas. *Heredity*, *89*(5), 380-386.

This paper discusses the origins of cacao. The authors conducted experiments in which DNA from 102 samples of cacao from 25 countries was extracted and analyzed using RFLP analysis and Microsatellite analysis. The paper focuses on the genetic origins of the varieties of cacao cultivated by the Mayans in Central America. Based on their experiments the authors found that the cacao grown by the Mayans originated in the Amazon and that their samples were closely related to Colombo-Ecuadorian types. They suggest that cacao varietals were brought by people from South America to Central America. This study builds on the literature of Cheesman in the 1940's, Chatt in the 1950's, and Shultes in the 1980's. It contradicts theories of a simultaneous and separate development of cacao varieties in Central and South America such as those put forth by Cuatrecasas in 1964, Cope in the 1970's, Wood and Lass in the 1980's, De la Cruz *et. al.* in 1995. The authors studies and their analysis of the results are a strong step in settling the long running debate about the genetic origins of cacao. Motomayor has become a leading scholar regarding the origins and spread of the cultivation of cacao. With the origins of cacao settled, the disbursement of cacao types, particularly among islands, remains an interesting study in and of itself.

2. Almeida, A. A. F. D., & Valle, R. R. (2007). Ecophysiology of the cacao tree. *Brazilian Journal of Plant Physiology*, 19(4), 425-448.

This article focuses on the growth and development of the cacao tree. The authors discuss the processes and characteristics of early growth in cacao trees and note the most important requirements for growing healthy productive trees. They also describe the flowering process which has been helpful in my hand pollinating efforts. The section of the paper dealing with cacao root systems aids me in determining where to plant cacao trees in my research and an extensive section on flushing, the production of new vegetative growth is helpful for me to fully understand the health of cacao trees. Published in 2007, this paper helps to fill gaps in earlier literature such as Eileen Chatts book, *Cacao: Cultivation, Processing, Analysis.*

3. Ajewole Davies Ojo & Iyanda Sadiq, (2010). Effect of Climate Change on Cocoa Yield: A Case of Cocoa Research Intstitute of Nigeria (CRIN) Farm, Ibadan, Oyo State. *Journal of Sustainable Development in Africa,* Vol. 12, No. 1.

The authors of this paper focus on climate affects cocoa yields in Ibadan, Nigeria. Through their research we come to see that temperature is a more important factor than rainfall on crop production and yield. It is stated in the paper that the optimal amount of rain is between 900mm and 1000mm and the optimal temperature is 29° C for this region of Africa. The paper focused on data collected from surveys of cacao farmers, production data CRIN experimental farm and climate data from the meteorological department of CRIN. The data is analyzed and shows the correlation between rainfall and temperatures to cacao in terms of pod yields. The authors make recommendations to maximize productivity and call for more research. Another interesting facet is that the authors identify 1874 as the year of introduction of cacao to Nigeria, by way of the Spanish island Fernando Po. This is of interest to Island Studies students and to those interested in the disbursement of cacao through out the world. The data on Nigeria's climate and cacao production is useful in understanding weather and climate change on productivity of cacao crops. English may not be the authors first language but the article is understandable and informative although its focus is narrow and specific to one area of Nigeria.

4. Jagoret, P., Michel-Dounias, I., Snoeck, D., Ngnogué, H. T., & Malézieux, E. (2012). Afforestation of savannah with cocoa agroforestry systems: a small-farmer innovation in central Cameroon. ***Agroforestry systems*****,** ***86*****(3), 493-504.**

This paper looks at deforestation traditionally associated with cacao production in Ivory Coast and Cameroon and contrasts it with afforestation and the implementation of agroforestry production methods. Agroforestry methods are increasingly being accepted as helpful in climate change mitigation as indicated by other articles included in this annotated bibliography. This paper compares the cacao yields of 157 grassland plantations and 182 agroforestry plantations. This is a large enough sample to give credibility to the authors study. They credibly suggest that cacao cultivation in Cameroon using agroforesty methods of agriculture can be a reforestation driver. This paper also shows resilience and adaptation to farmers concerns about declining cacao production and yields due to climate change. Although this paper focuses strictly on Cameroon it works with other papers listed here to help clarify the broader picture of cacao production and climactic conditions.

5. Moser, G., Leuschner, C., Hertel, D., Hölscher, D., Köhler, M., Leitner, D., ... & Schwendenmann, L. (2010). Response of cocoa trees (Theobroma cacao) to a 13-month desiccation period in Sulawesi, Indonesia. ***Agroforestry systems*****,** ***79*****(2), 171-187.**

In this well researched paper the authors acknowledge the effects of ENSO related events and their likely exacerbation due to climate change. They conduct rigorous experiments to test drought resistance of cacao trees in Indonesia. The description of the root biomass size and location is informative for my attempts at growing cacao. The paper is thoroughly researched with an extensive charts, photographs and graphs and includes a deep reference section. Through the authors research and experiments they show that cacao has some drought resistant

characteristics in vegetative and root growth. However, pod production yield is reduced during drought periods and particularly during El Nino related weather events.

6. Dias, L. A. D. S., Barriga, J. P., Kageyama, P. Y., & Almeida, C. M. V. C. D. (2003). Variation and its distribution in wild cacao populations from the Brazilian Amazon. *Brazilian Archives of Biology and Technology*, *46*(4), 507-514.

This paper contributes to the discussion about the origins of cacao varieties. Combined with Motomayer *et. al.* this work shows further evidence suggesting cacao originated in the Amazon region of present day Ecuador, Colombia, Peru, and Brasil. This paper also represents another well researched study, including many graphs and charts. The limits of the research presented in this paper is that it was collected over only a one year period. The contributions to the literature are that this study encourages wider sampling from diverse regions of the Amazon basin.

7. Leibel, N. T. M. (2008). *The environmental constraints on cocoa (Theobroma cacao) production in north Australia.* (Unpublished doctoral dissertation). University of Technology, Sydney.

I chose to include this dissertation because the author is writing about a topic similar to my own focus, except that his geographic focus is Australia while mine is currently Florida. This dissertation is well researched and organized. At 263 pages with 31 pages of reference this work provides a great deal of information relevant to my own studies. The author focuses on a geographic area not known to produce cacao and addresses some of the same problems I am encountering here in Florida. A focus on cold night time temperatures and shade trees with in agroforestry systems are prime importance in this study. The study found some success in growing cacao in some areas of Australia and some locations were deemed unsuitable. The paper suggests the possibility of growing cacao in Australia under agroforestry systems with selected varieties and encourages further study.

8. Rice, R. A., & Greenberg, R. (2000). Cacao cultivation and the conservation of biological diversity. *AMBIO: A Journal of the Human Environment*, 29(3), 167-173.

This work supports other papers in this annotated bibliography regarding agroforestry agricultural methods being beneficial to biodiversity and climate change mitigation. The authors also promote the use of agroforestry methods of shade grown cacao as being positive for a more sustainable and equitable system for cacao farmers. The paper conducts a comparison between cacao grown under old growth tropical forests, intentionally polycultural plantations of cacao and monocropped cacao plantations with no shade growth. Aside from climate and biodiversity concerns this paper also addresses the plight of the people directly involved in small scale cacao production which contributes to the scope of the material of this course and is not discussed in many of the other papers in this list.

9. Condit, R., Hubbell, S. P., & Foster, R. B. (1996). Changes in tree species abundance in a neotropical forest: impact of climate change. *Journal of tropical ecology*, *12*(02), 231-256.

The focus of this work is an 8 year study on diversity of species of trees on the Barro Colorado Nature Monument. This site is of interest to Island Studies students because the site is a nature reserve on an 1500 ha island that was created due to the completion of the Panama canal in 1914. This site has been a preserve since 1923 and the study focuses on 219 tree species. Although cacao is not the focus of the study it is one of the trees involved in the study. The data included in this paper focuses on a 25 year period of more severe dry seasons and reduced moisture and concludes that 10% of the species within the reserve are under threat of extinction. The paper represents a long term study of the climactic conditions in Panama. This is of relevance in that it provides baseline for climate change data and affects on tropical forests.

Somarriba, E., Cerda, R., Orozco, L., Cifuentes, M., Dávila, H., Espin, T., & Deheuvels, O. (2013). Carbon stocks and cocoa yields in agroforestry systems of Central America. ***Agriculture, Ecosystems & Environment*****,** ***173*****, 46-57.**

This paper, like others on this list, talks about the benefits of agroforestry systems and cacao production. This paper goes beyond many of the others and focuses on carbon sequestration within cacao growing agroforestry systems. The authors convincingly argue that shade grown cacao production that takes place in biodiverse polycultural plots has benefits for biodiversity and stocking carbon. This paper is further evidence of shade grown cacao production as viable, sustainable, equitable as well as being beneficial to biodiversity and climate change mitigation and adaptation. This is a well researched piece of work and reinforces some of the ideas discussed in other papers presented here.

11. Boza, E., Gutierrez, O., Motomayor, J.C., Amores, F., Cedeno-Amador, S., Tondo, C., & Livingstone, D. (2014). Genetic Characterization of the Cacao Cultivar CCN 51: Its Impact and Significance on Global Cacao Improvement and Production. ***Journal of American Society of Horticultural Science,*** **139(2), pp 219-229.**

This article was given to me by one of the authors, Dr. Osman Gutierrez, during a visit to the USDA agricultural research station in Miami. It is a study of a variety of cacao known as CCN 51. This variety was developed in the 1960's by H. Castro and became adopted by farmers as early as 1965. The authors, who are cacao geneticists working in Ecuador and with the USDA in Miami, decoded genetic material of this variety of cacao to discover its complex genetic background. They discover that many of its characteristics are not characteristic of traditional 'nacional' cultivars. The nacional varieties are highly prized for the flavour of the chocolate produced from them but are susceptible to disease and are in the mid-range in terms of productivity. They conclude that the high productivity and disease resistance are of great value to producers and, in many ways, they are correct. However they neglect the fact that CCN 51 beans produce chocolate that does not have the esteemed flavors of Nacional cultivars. I have made chocolate from beans from both cultivars and have found that the Nacional varieties have a flavor far exceeding that of CCN 51. While the authors conclude that CCN 51 is a valuable genetic resource and an important part of breeding and selection programs around the world I would suggest that it represents a compromise of flavour for disease resistance and productivity. The farmers I have worked with in Ecuador actively resist planting CCN 51 and focus on other cultivars known for their flavour.

12. Bisseluela, D., Missoup, A., Vidal, S. (2009). Biodiversity Conservation, Ecosystem Functioning, and Economic Incentives under Cacao Agroforestry Intensification. *Conservation Biology,* 23(5), pp. 1176-1184.

This article looks at biodiversity and agricultural systems used to grow cacao. The research was conducted on 17 cacao farms in Cameroon. The authors state that demand for cacao is increasing yearly and expected to double by 2050. This pressure is leading to deforestation as farmers attempt to grow more cacao to meet the demand. Traditionally, cacao is a shade grown crop that requires canopy trees, especially for the younger cacao trees. Advancements in breeding programs have resulted in varieties of cacao that can tolerate more sun. Such varieties include CCN 51 which was discussed in the previous entry of this annotated bibliography. The authors created a profitability index on each of the farms using annual income per hectare. They also measured insect abundance, particularly ants, to see if biodiversity affected profitability one way or another. I found it somewhat odd to use only ant species as indicators of biodiversity and thought that a count of species encountered in a specific area as compared to another would be a better method.

They're results were inconclusive in terms of profitability but it can be argued that biodiversity is valuable in and of itself. The authors found more varieties of ant species in traditional canopy shaded agroforestry management systems than in newer intensive growing methods. Despite not finding an economic benefit to the traditional multiple tree species shade grown systems when compared to monoculture methods the authors argue that biodiversity should be encouraged among small cacao farmers and certification incentives may be a way to help increase income to small landholders.

In my own experience, in Ecuador and elsewhere, small landholders insulated themselves against the risk of fluctuating markets precisely through the biodiversity of their landholdings. At times this related to subsistence crops intermingled with cacao and also other cash crops grown in the same areas as the cacao trees. I also think that monoculture systems are less resilient than shade grown agroforestry systems and exhaust soil nutrients more rapidly.

13. Rice, R., & Greenberg, R. (2000). Cacao Cultivation and the Conservation of Biological Diversity. *Ambio,* **29, (3), pp.167-173.**

In this article the authors discuss the various methods of cacao production. They identify three main methods in terms of the amount of shade provided for the cacao trees. The first, which is referred to as "rustic cacao", is planting cacao in thinned primary forests or in secondary forests. In the second method the shade trees are planted with the cacao trees and the third method the authors discuss is one in which no shade is provided. The claim of the article is that cacao trees planted in primary or secondary forests (whether thinned or not) is the most beneficial in terms of biodiversity. This seems obvious to me and in my experience this has been the case. The second method that they discuss is interesting in that in my experiments in Florida I have attempted to plant cacao trees in shaded areas but have planted banana trees nearby because bananas are fast growing and can provide shade for the young cacao trees. In a sense I am combining the first two methods described by the authors of this article.

While shade is most important when the cacao trees are young I have not had good experiences growing cacao in full sun. The cacao varietal CCN 51 is one type of cacao that can grow in full sun but in my experience it does not yield flavourful cacao beans and I would

choose other varieties. Also, shadeless cacao farms are often use significant amounts of agrochemicals whereas the so-called rustic cacao often uses none.

One interesting facet of this article is that the authors are concerned with deforestation related to cacao production and they encourage increasing the long-term productivity of existing farms and reinvigorating old or abandoned cacao farms. They do not encourage the continuation of clearing new land for cacao growth. If it is true that monoculture methods exhaust the soil more rapidly than agroforestry techniques then the tradeoff would seem to be the low input, low yield of the "rustic" cacao compared to a temporary high yield of shadeless mono-cropping systems that leaves the area unable to sustain cacao production at all.

Considering that the "rustic" method also has an exponentially higher amount of biodiversity of species it would seem that the monoculture method is unsustainable and sacrifices long term productivity as well as biodiversity for short term gains of mediocre cacao.

This article does not focus on a particular country as do many of the others that I am reading and is thus more general. It does have many graphs, maps and charts which are interesting and informative for my studies.

14. McShea, A., Ramiro-Puig, E., Munro, S., Casadesus, G., Castell, M., & Smith, M. (2008). Clinical benefit and preservation of flavonols in dark chocolate manufacturing. *Nutrition Reviews*, Vol. 66(11), pp.630–641.

This article relates more to processing cacao beans than to growing them and is thus rather different than most of the readings that I have been doing. This piece begins by acknowledging that there are health benefits attributed to some of the compounds in dark chocolate. This article focuses on flavonal antioxidants and how these compounds are affected during the processes required to turn cacao beans into chocolate.

This is a helpful article because it reviews exactly what is happening to the antioxidants during processing and to date there has not been enough research in this area. The lack of research has led to many chocolate companies promoting health benefits, often when these same companies end up destroying or reducing antioxidants through the processing methods. This is particularly the case with flavonals because they are astringent and bitter and some companies try to mask or reduce these characteristics.

By analyzing the chocolate making process and reviewing recent pharmacological research the authors provide an opportunity to discover what chocolate making procedures can result in a finished product that retains the most health benefits. Hopefully this will lead to better educated consumers and curtail less scrupulous chocolate makers from making false claims and further confusing the issue.

15. Ken-Ichi Miyaji, Walny S. da Silva & Alvim, P. (1997). Productivity of Leaves of a Tropical Tree, Theobroma cacao, Grown Under Shading, in Relation to Leaf Age and Light Conditions within the Canopy. *New Phytologist*, Vol. 137, (3), pp. 463-47.

The authors of this article have engaged in an in-depth and thorough examination of the functioning of cacao leaves in shade grown cacao plantations. The article examines which areas of the foliage of the cacao trees are most productive and at what times during the 24 hour cycle of the day. They found that the leave weight and moisture content varied depending on where on

the tree the leaves were located. Leaves on the upper canopy of the cacao trees had more photosynthetic activity but had less longevity than those leaves located lower on the tree. This would seem to make sense as these leaves would receive more light.

The authors do not consider or study cacao grown in direct sunlight. The research was conducted in Brasil and the article contains useful climate data relating to temperatures and rainfall. The main benefits to this article, in relation to my studies, would pertain to how I go about pruning cacao trees as well as siting planting locations. In terms of planting locations this article is helpful in identifying the correct amount of shade to provide cacao trees.

16. Oyekale, A. Bolaji, M., & Olowa, O. (2009). The Effects of Climate Change on Cocoa Production and Vulnerability Assessment in Nigeria. *Agricultural Journal,* 4 (2), pp. 77-85.

In this, as well as previous articles, I learned that cacao was introduced to Nigeria in 1874. More recently, according to the authors of this article, cacao production in Nigeria has been in decline. One of the reasons for this has been climate change. The authors study climate variables on all major facets of cacao production, from seedling to harvest. This article is one of the most relevant to what I am interested in and studying that I have read thus far. The authors are looking specifically at how climate change is affecting cocoa production. The research they conducted was done in Nigeria although it would seem to be applicable to other areas as well. After a section on climate change and how cacao is particularly susceptible the authors look at the possibility of adaptation by known diseases. I found this section particularly interesting and had not read much about this before.

This article is well organized with the research questions and objectives clearly articulated. After looking at climate variables and cacaos vulnerability the article looks at which farmers are most vulnerable to the shocks and decline of cacao production in Nigeria. I found this quite interesting and it could be looked at partly as an ethnography of Nigerian cacao farmers. The research conducted also looked at whether the farmers involved were male or female, whether they had access to agrochemicals and also analyzed what types of coping strategies were utilized by these farmers.

The article contains several interesting visual components. The most interesting, and also unsettling was a chart that indicated that 91.9% of respondents indicated that they had experienced climate related problems that negatively affected their cacao crops. Rainfall was the predominant problem for most respondents.

The article seems to be directed (or at least contains recommendations for..) the Nigerian government and suggests more research by, and more resources from, the state. They propose a program of breeding to find drought resistant varieties and training for farmers. There does not seem to be a call for action to reduce climate change or for mitigation ideas.

17. Motamayor, JC., Risterucci, A., Heath, M., & Lanaud, C. (2003). Cacao domestication II: progenitor germplasm of the Trinitario cacao cultivar. *Heredity,* 9, pp. 322-330.

I selected this reading because I was interested in the origins and spread of cacao and Juan Carlos Motomayor is quickly becoming the authority on the subject. He is currently working at the USDA research site in Miami which I have had the opportunity to visit and speak with some of the geneticists on his team.

These authors, along with others included in this annotated bibliography, seem to be close to definitively determining the origins of cacao through genetic research. Most of their published work shows that cacao originated in the area we now call Ecuador/Colombia/Brasil. This has been a long standing debate within academic circles and amongst cacao farmers as well as chocolate makers. I find the whole topic very interesting although the technical aspects of these authors work is beyond my comprehension.

With the debate surrounding the origins of cacao apparently settled it is still of great interest to me to study the spread of cacao around the world in what has come to be known as the "cacao belt" (between 20 degrees N and 20 Degrees S latitude). As changes in climate occur it is fascinating to me to see the known cacao growing region of the world changing. There is now a cacao industry in Hawaii and efforts are being made by some to grow cacao in Australia. Others, myself included, are trying to grow cacao in Florida. Articles such as this provide data on the origins of cacao and efforts of farmers and agronomists are challenging the limits of where cacao can be grown. I wonder about how climate change will affect the known growing regions and whether we will see cacao grown in areas previously considered unsuitable.

18. Lin, B. (2011). Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. *BioScience*, Vol. 61, No. 3, pp. 183-193

This article discusses a variety of crops and includes cacao in its scope. The author discusses how crop diversification can help mitigate the negative effects of climate change. While the article discusses a variety of crops, cacao is used as an example because cacao is often grown in conjunction with other crops. While this is primarily due to many varieties of cacao requiring shade it is important because shade grown cacao farms can be analyzed in terms of resilience. The authors premise is that a mix of crops grown together is more resilient to problems related to climate change. Some of her arguments relate to diverse agroforestry systems being able to tolerate temperature fluctuations. Other arguments point out that areas of high diversification are more resistant to pests and diseases which are often exacerbated by climate change.

This article bolsters other readings I have done that suggest mixed crop agroforestry methods are the most sustainable method for cacao production. In addition they are also more beneficial to biodiversity and are useful to farmer's abilities to cope with climate related problems. Biodiversity and crop diversification seem to reduce vulnerability to climate change.

This article, while not specifically related to cacao, seems to add credence to the idea that shade grown cacao, produced on lands with other cash crops, subsistence crops and canopy trees, is the most environmentally sound production method and is also the most beneficial in terms of long term productivity.

19. Tscharnkte, T., Shonil, A., Buhori, D., Faust, H., Hertel, D., Ischer, D., Juhrbandt, J., Kessler, M., Perfecto, I., Scherber (2011) Multifunctional shade-tree management in tropical agroforestry landscapes. *Journal of Applied Ecology*, Vol.48, pp. 619–629.

This is another article which studies shade grown cacao, however this article focuses on both short and long term ecological benefits on agroforestry methods. Among the benefits the many authors of this article cite include drought resistance, enhanced biodiversity, fertility of soil, the ability of these terrains to sequester carbon as well as benefits in terms of managing pests and diseases. The focus of this article is on ecological benefits and as such it is a good

accompaniment to previous articles that I have read that analyze economic benefits. This is one of the few articles that I have read this semester that emphasizes ecosystem services over a strictly economic approaches. The authors also suggest that certification systems can act as an incentive for farmers to maintain shade grown cacao agroforestry methods.

If, as many of the other articles I have read suggest, cacao and chocolate consumption will increase to as much as double current levels by 2050 then the methods of production become extremely important. Cacao cultivation, if done according to this and other articles, could be a crop that does not contribute to increased deforestation.

This article has many graphs and charts and also includes photographs of various types of cacao cultivation methods. The ideas here mesh well with much of what I have been reading about the benefits of agroforestry techniques. In addition to benefits cited in other articles in this list agroforestry is credited with helping reduce erosion. In areas affected by climate change this is yet another aspect of resiliency. With all of the information about the benefits of these methods over mono-cropping systems it is hard to see why some agencies are promoting cacao varieties such as CCN 51 for growth in orchards. Perhaps this reasoning is due to a limited focus on short term economic factors.

20. Field, M., (2008) Climate Change and the Future of Taste. *Gastronomica: The Journal of Critical Food Studies*, Vol. 8, No. 4. pp. 14-20.

This article is not specifically related to cacao but cacao is included in its analysis. The focus is on the loss of crops due to climate change and the authors premise is that with the decline of certain crops humans will lose their taste, and memory of taste, for certain foods including cacao. He discusses the possibility that as some areas will no longer be able to produce certain crops because of climate change, these crops may be grown in areas previously considered unsuitable. This is directly relevant to some of the themes I am looking at. He considers this position to be overly optimistic and questions whether large corporations would have the foresight or motivation to move cultivation from one area to another. I think this may well be true but he does not take into account the actions of individuals and dismisses this component without considering historical contributions of individuals to the spreading of crops. For example, a small handful of fruit hunters (Bill Whitman and David Fairchild being among the most prolific) have completely altered the North American diet through their collecting expeditions. Another case would be the cacao industry in Hawaii. While there was some cacao in Hawaii for at least one hundred years, it only took the efforts of one farming couple to convince the Dole corporation to invest in cacao plantations there. Likewise, we have only to look at the rat population in the Galapagos to see that at times all it takes is one introduction to change the whole dynamic.

The author does discuss food history and what he describes as “taste extinctions” but the most interesting facet of this article is the section on what he terms back breeding. In our relentless pursuit of profits farmers as well as corporations have bred crops with the aim of ever higher yields and disease resistance while breeding out other characteristics. I was unaware that some companies are back breeding, that is they are selecting strains that have characteristics that have been bred out of the most popular current strains because some of these characteristics may well be beneficial or even crucial to there survival. I found this quite interesting as I ponder cacao varieties and the work of geneticist like Motomayer among others. This is relevant to

what I am considering as I focus on cacao cultivation, climate change and fine flavoured chocolate.