Chasing an End to Perpetual Deforestation

Visualizing Land Potential to Address the Constant Struggle of the Brazilian Smallholder

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Owing to a troubled history, poor environmental conditions, and lack of economic opportunity, small farmers in the Brazilian Amazon must clear increasingly remote areas of forest as their present land degrades. Agroforestry systems, for their enhanced sustainability and profitability, have been qualified as a potential solution to this perpetual struggle. Despite widespread agroforestry development initiatives, there remains to be a simple, comprehensive measure of environmental suitability for these systems across Amazonian region under agricultural cultivation. To that end, this project uses GIS modeling to evaluate the relative suitability across the Brazilian Amazon for agroforestry systems. The result is a series of "suitability maps" that display the relative fitness of the study region for crops most typically associated with these farming operations.

The National Integration Program and the Plight of the Small Farmer

Although large-scale agribusiness is commonly condemned as the agent of Amazonian rain forest destruction, the small farmer plays a significant role. According to a 2002 study, the share of deforestation attributable to small farmers may in fact be as high as 31%.[1] Constant land-clearing on the part of the smallholder does not show irresponsibility in resource management; smallholders are major stakeholders in the sustainability of the region's agricultural potential. Instead this perpetual land clearing reflects dependence on a largely unsustainable agrarian situation. Owing to the poor quality of Amazonian soils, the cultivation of typical annual crops in the absence of sufficient fallow periods or nutrient replenishment mechanisms degrades the land very quickly. As smallholders generally do not have access to the capital necessary for expensive inputs, such as chemical fertilizer, they're forced to clear more land as they degrade their existing arable land through overuse.[2]

There are thousands of small agriculturalists in the Eastern Amazon, and their presence is no accident. The majority of these farmers in fact hail from other regions of Brazil. The local farmer population is low, as this land was largely untouched rainforest up until the second half of the twentieth century. The 1964 military coup — a backlash against populism and the perceived threat of communism — however, brought irreversible changes

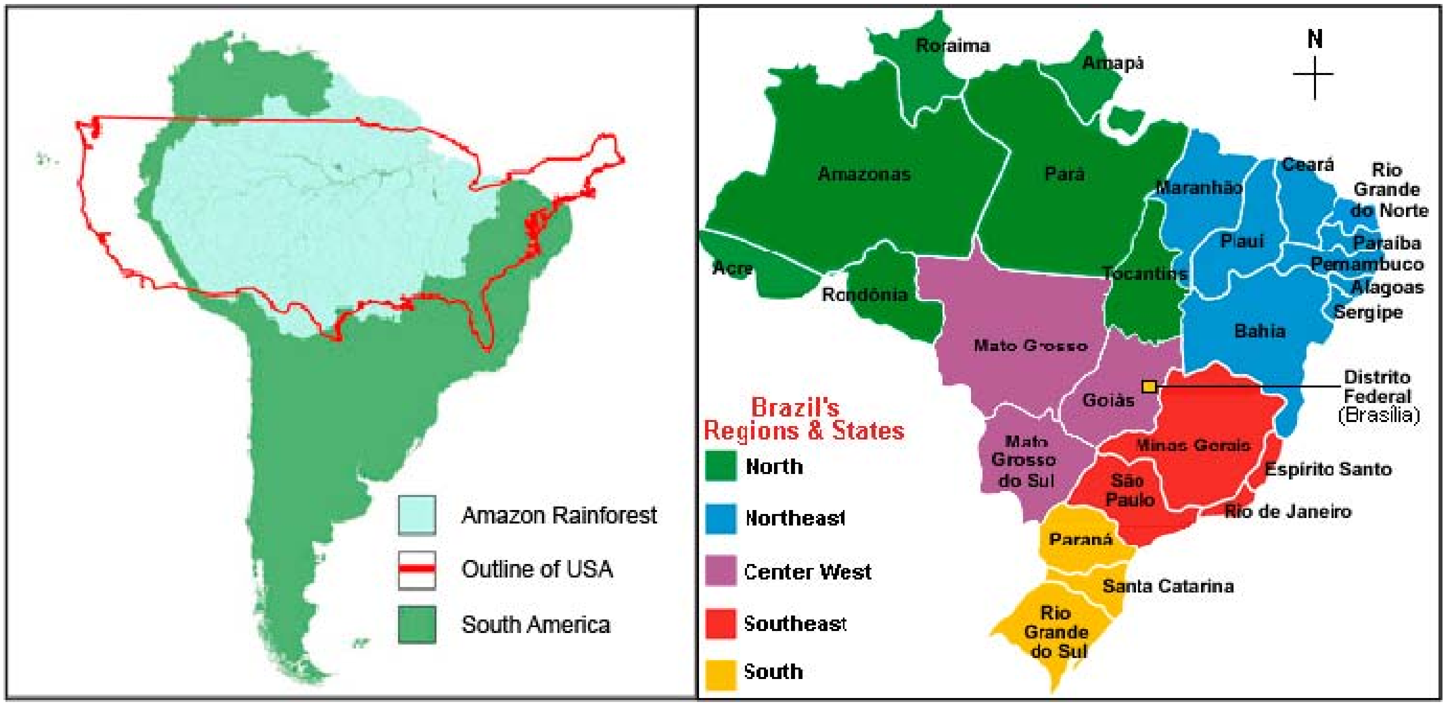

Figure 1. ***Left:*** **South America with the Amazon basin on display, and an outline of the U.S. for reference.** ***Right:*** **The states and regions of Brazil.**

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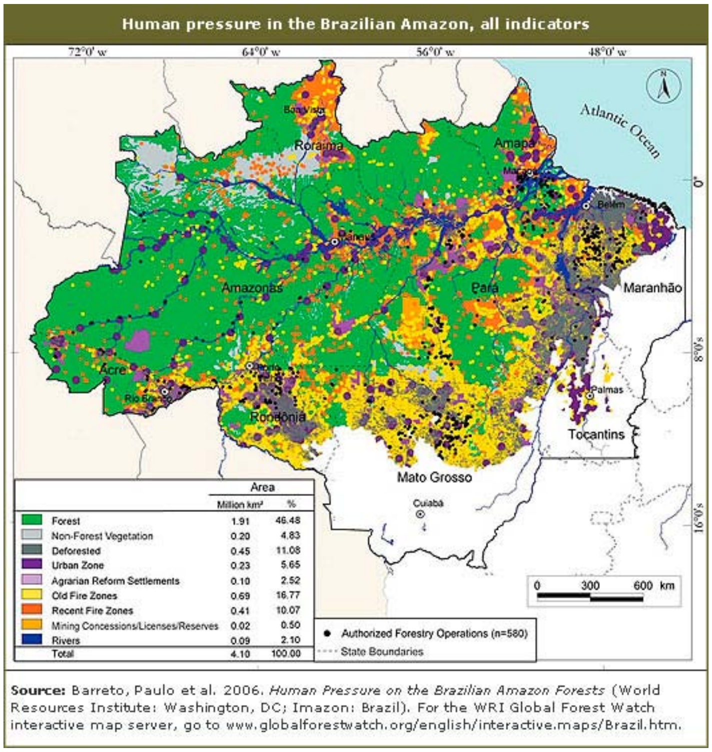
to the region. Wary of border changes that had recently taken place in Europe, and in recognition of the overwhelmingly high concentration of the Brazilian population along the coastline, Brazil's military regime feared losing the Brazilian interior to other nations. The government's solution became what was known as the National Integration Program (PIN[3]). Throughout the 1970s, the PIN encouraged small farmers, largely from the impoverished states of Maranhão, Piauí, and Bahía of Brazil's northeast region, to migrate to the Amazonian frontier under the promise of, "Land without people for people without land."[4]

Land ownership was not so simple for the millions of smallholders, commonly known as Colonos, upon arrival to the new frontier. Despite ardent promotion of the PIN to preserve ownership of the interior, the military regime aspired to make Brazil competitive in international markets for produce. In a somewhat contradictory move to the PIN, they sought to achieve this by industrializing and consolidating the agricultural sector.[5] This gave Brazilian agribusiness the justification it needed to place claims on enormous tracts of Amazonian land, effectively forcing smallholders to increasingly marginal areas; that is, regions with poor access to passable roads and other essential forms of infrastructure.[6] In addition, because of the limited influence of the rule of law, large landowners often backed by hired guns mercilessly exerted their authority. These *latifundiarios* made extravagant land claims, often supporting them with forged title deeds. All of this served to drive smallholders further out into remote locations along the deforestation frontier.[7] Although this began in the late nineteen sixties, this highly unequal situation in the Amazon region persists; small farmers must clear increasingly marginal areas as their land degrades.



	Area Million km²	%
🟩 Forest	1.91	46.48
⬜ Non-Forest Vegetation	0.20	4.83
⬛ Deforested	0.45	11.08
🟪 Urban Zone	0.23	5.65
🟪 Agrarian Reform Settlements	0.10	2.52
🟨 Old Fire Zones	0.69	16.77
🟥 Recent Fire Zones	0.41	10.07
🟧 Mining Concessions/Licenses/Reserves	0.02	0.50
🟦 Rivers	0.09	2.10
Total	4.10	100.00

Source: Barreto, Paulo et al. 2006. *Human Pressure on the Brazilian Amazon Forests* (World Resources Institute: Washington, DC; Imazon: Brazil). For the WRI Global Forest Watch interactive map server, go to www.globalforestwatch.org/english/interactive.maps/Brazil.htm.

Figure 2. Human pressure in the Brazilian Amazon.

Agroforestry: A Potential Solution

Agroforestry systems are farming operations that incorporate perennial crops and trees along with annuals into complex multi-crop operations. Much academic work and practical experience have qualified them as sustainable alternatives to the traditional farming model. Valued for their ability to cycle nutrients and protect against erosion, pests, and disease,[8] agroforestry systems largely eliminate the need for constant land clearing.[9] The sustainability of these systems, combined with their increased profitability relative to the traditional operation[10] has made agroforestry a potential key to ending the smallholder's perpetual migratory status, and thus the subject of much local and international attention.

Agroforestry systems may be lucrative once established, but implementing them requires expensive credit, inputs, and technical knowhow that many don't have access to, along with more favorable environmental conditions.[11] For this reason agroforestry systems maintain an extremely small share of land use in the region.[12] Nevertheless, the Brazilian government and various NGOs have within the last several years begun an array of initiatives that provide the access to the necessary resources for the implementation of these complex systems. Once implemented, however, agroforestry systems can typically be managed at relatively the same cost as a typical mono-crop operation. These initiatives, necessary to "start up" the use of agroforestry, are widespread. With such a volume of organizations now working in this field, the extent of these efforts encompasses the majority of the Eastern Brazilian Amazon.

Suitability Mapping: A Key Component

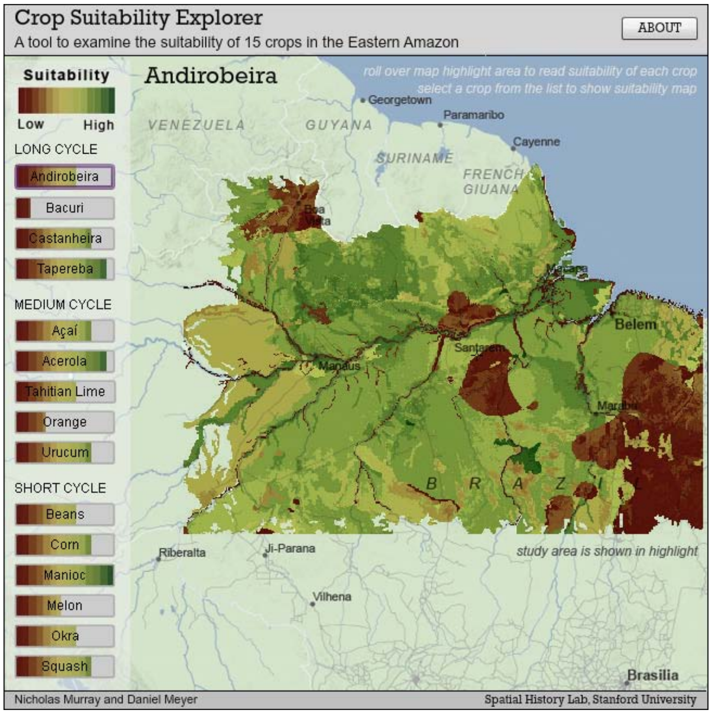
Despite the high concentration of agroforestry development initiatives taking place in this region, there remains to be a simple, comprehensive measure of relative agricultural suitability across the Eastern Brazilian Amazon for agroforestry systems. As environmental factors such as soil quality, susceptibility to erosion, and climatic conditions can be a central constraint to the implementation of agroforestry, it's important to assess the region with respect to these variables.

In recognition of the importance of such an assessment, this project evaluates the relative suitability of the region for agroforestry systems through the use of GIS modeling, producing a series of agroforestry "suitability maps." Aiming for comprehensive analysis, these maps extend from the coast to the interior city of Manaus and from Brazil's northern border down to the southern edge of the Amazon basin. Ideally, this model will aid in the expansion and development of agroforestry systems through a number of channels. Primarily, such a model has the potential to inform those working in agroforestry development as to where to allocate resources, as the least suitable areas will require the most attention. These maps can also serve to rationalize differences in the success of various agroforestry implementation initiatives that have already taken place, and predict the relative success of impending initiatives, all with respect to environmental suitability. In addition, this comprehensive measure of the natural potential of the land reveals where low input farming, attractive for its low capital costs, has the highest chance of success. Finally, one would expect these maps to aid in the expansion of the findings of site-specific agroforestry adoptability studies to other areas in the region by adjusting for environmental differences.

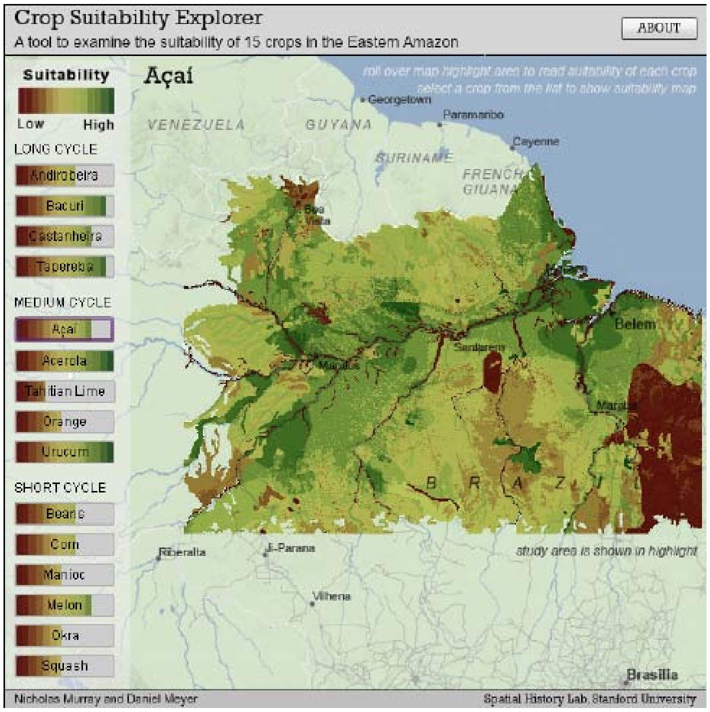
The value of agroforestry systems comes in cultivating multiple crops on a single plot of land. Therefore, the visualization below demonstrates the suitability distribution of the selected crop, along with suitability measures of the other crops according to the location of the user's mouse. This allows the user to obtain a quick sense of the suitability for any given combination of crops.

Many agro-suitability maps already exist,[13] but none as specific to crops associated with agroforestry systems. Filling this gap involves building a model around crops relevant and specific enough so as not to reinvent the wheel of a more generalized agricultural suitability assessment. For this reason, this project constructs suitability maps with respect to all the 15 individual crops included in the majority of INCRA[14] agroforestry initiatives in the region. These crops include the typical annuals along with both native and non-native perennial fruits and various trees used for their timber and non-timber products. The subject crops are organized into three categories that refer to the timescale along which they're typically harvested. "Short cycle crops" refers to annuals, or produce that can be harvested within one year. The other two categories, "medium cycle" and "long cycle" crops respectively refer to perennial fruits and trees of more intermediate, and much longer time to harvest. For each crop included in the INCRA initiatives, this project developed a suitability map with respect to a list of environmental variables. The models include data on soil type and quality, slope, so as to assess susceptibility

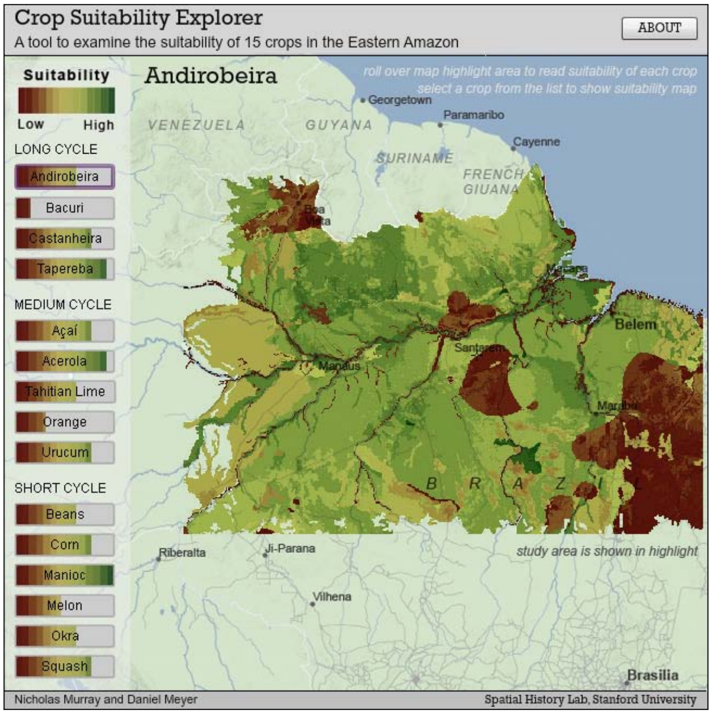
Figure 3. Suitability values for short, medium, and long cycle crops. **Please click here to view the full interactive online version.**



Long cycle example: Andirobeira suitability in Santarem.



Medium cycle example: Açaí suitability in Santarem.



Short cycle example: Beans suitability in Santarem.

to erosion, temperature, and precipitation levels. For more information regarding the process behind building the model, please refer to Appendix A.

Results

Using the model to combine climatic and land data into a suitability index yielded unique maps for each of the 15 target crops. Prime locations for each crop tend to be concentrated in areas of quality soil, as nutrient rich soil is rare in the Amazon. Because poor soil is well distributed and covers the majority of the study region, and as temperature was rarely found to be a limiting factor in terms of suitability, areas with low suitability ratings are more commonly those with either too little or too much precipitation. Crops would either be subject to excessive rainfall to the point where root rot becomes a threat, typically the case with annuals, or rainfall insufficient enough to require the incorporation of irrigation systems. This was typically the case with crops native to the rainiest areas of the Amazon, such as Açaí, Urucum, and Taperebá.

Map Use, Constraints, and Limitations

The first thing to keep in mind in the use of these suitability maps is that they display relative measures. The rating from zero to ten has no unit, and therefore cannot be used as an absolute measure of agricultural suitability. The value of these maps lies instead in the ability to compare areas as small as 41 hectares, or the minimum area for comparison that the data's resolution allows for.

Although this model incorporates the most influential environmental factors, there are many variables that, due to limited time and resources, fell outside the scope of this project. Solar radiation — although rarely a limiting factor in the Amazon — is somewhat influential, and was not included. In addition, a more comprehensive suitability map would have moved beyond strictly environmental factors and incorporated anthropogenic influences such as infrastructure, market access, income levels, and differing land uses. There's no doubt that a map incorporating these factors would yield a different distribution of agricultural suitability across the study region. Therefore, it is most important that the user recognizes these maps as demonstrating environmental suitability only.

Finally, one must not lose sight of the fact that this is a top-down model. That is to say, these maps measure suitability according to widely accessible data, and not to any influence of the actual farmer and his or her agricultural operation. This is yet another reason not to regard these maps as comprehensive measures of the viability of agroforestry, as the success of such complex operations depends heavily on the farmer managing them. In essence, these maps are meant to provide context in which to work with farmers on the ground much more than to be a final answer on the overall feasibility of agroforestry systems.

Despite these limitations the resultant maps provide an accessible measure of environmental suitability for agroforestry systems. The significant variation in suitability distribution across the different maps illustrates the value of constructing a crop specific suitability models, as they provide a more characteristic perspective. Again, these maps are not the final answer on the suitability of a given area for agroforestry systems. Rather, they have the potential to serve as integral players in the movement towards a more comfortable and sustainable future for the Amazonian smallholder population, and for the forest itself.

Ideally, initiatives aimed at helping the Amazonian smallholder achieve a better quality of life will continue to develop. Although it's overwhelmingly popular to champion the preservation of the Amazon, such preservation cannot occur without addressing a commonly unrecognized ultimate cause: the continuing dependence of the smallholder population on constant land degradation. One cannot expect an agriculturalist struggling to make ends meet to have the long term preservation of the rainforest in mind. What must come first is establishment on the land, and the realization of a decent quality of life.

Please see page 5-6 for Appendix A: The Model Building Process.

End Notes

1. Geist and Lambin
2. Negreiros
3. Programa de Integração Nacional
4. Martins
5. Martins
6. De Jesus
7. Cointreau
8. McGinty
9. Smith
10. Yamada
11. Pacheco
12. Smith
13. GIS: A Window on Tropical Agriculture and Natural Resources.
14. The National Institute of Colonization and Agrarian Reform: The Brazilian federal agrarian reform agency

Appendix A: The Model Building Process

Data on soil type was derived from a comprehensive map of soil type coverage of Brazil produced by the Brazilian Institute of Geography and Statistics (IGBE). This project derived slope data from SRTM elevation files produced by the Consultative Group on International Agricultural Research (CGIAR). Finally, data on temperature and precipitation was averaged from data collected by numerous organizations over the past thirty years and compiled by the World Climate organization. Specific information regarding each individual crop's ideal growing conditions was derived from a number of sources, but came principally from the Brazilian Agricultural Research Corporation (EMBRAPA), the Secretariat for Agriculture, Irrigation, and Agrarian reform of the state of Bahía (SEAGRI), and the Food and Agriculture Organization (FAO).

Construction of the model began with classifying each soil type, and the region's varying levels of incline into seven categories ranging from zero to 60 percent grade. These two datasets were then combined in ArcGIS to yield a single entry for each unique combination of slope class and soil type. Each crop was subsequently given a "raw" score from zero to ten, ten being ideal, for each soil type by weighing measures of overall fertility, drainage capacity, nutrient retention, acidity, and susceptibility to erosion against the subject crop's ideal conditions. Each soil type was then assigned an "erosion multiplier" that would either magnify or reduce the negative effect of slope on agricultural suitability by incorporating the susceptibility of each soil type to erosion. Finally, for each crop, a "slope effect" was assigned to each slope class that reflected that individual crop's tolerance for incline. These measures were then incorporated into the following model to yield a rating between zero and ten for each pixel in the combined dataset, with respect to each crop.

$$L = R - Em$$

Where L is the land suitability score between zero and ten for each pixel, R is the crop's raw score for each soil type, E is the individual slope effect for each crop, and m is the erosion multiplier. Regarding climatic conditions, monthly temperature and precipitation data was isolated for each crop's individual growing season in the case of annual crops, and averaged on an annual basis for trees and perennials. These datasets, with respect to each crop, were subsequently reclassified, scoring each pixel on the same zero to ten scale. As the source material on each crop's ideal conditions typically provides an ideal temperature and precipitation value or range of values, these were given tens, while the other classes were given incrementally lower scores. Whether or not the subject crop is more drought tolerant or flood tolerant determined whether higher or lower levels of precipitation were given the higher descending scores. The same was done with temperature data; information on heat tolerance determined whether or not higher temperatures or lower temperatures were given the higher descending scores.

After the establishment of a score from zero to ten with respect to soil and slope, temperature, and precipitation for each subject crop, these scores were combined using Mendoza's "MCDM methodology" of combining already rated variables (on a common scale) simply by summing them with weights. Challenges arose in determining which weights to assign to which variables, as there is no real quantitative measure of the relative importance of land and climatic conditions. Considering that temperature and precipitation for the target crops in the study region are rarely limiting factors as compared to slope and soil quality, the land suitability rating was given the most weight (0.5) followed by temperature (0.3), and finally precipitation (0.2) as this factor is the most correctible with the incorporation of irrigation mechanisms. These weights completed the final suitability model:

$$S = c_L L + c_T T + c_P P$$

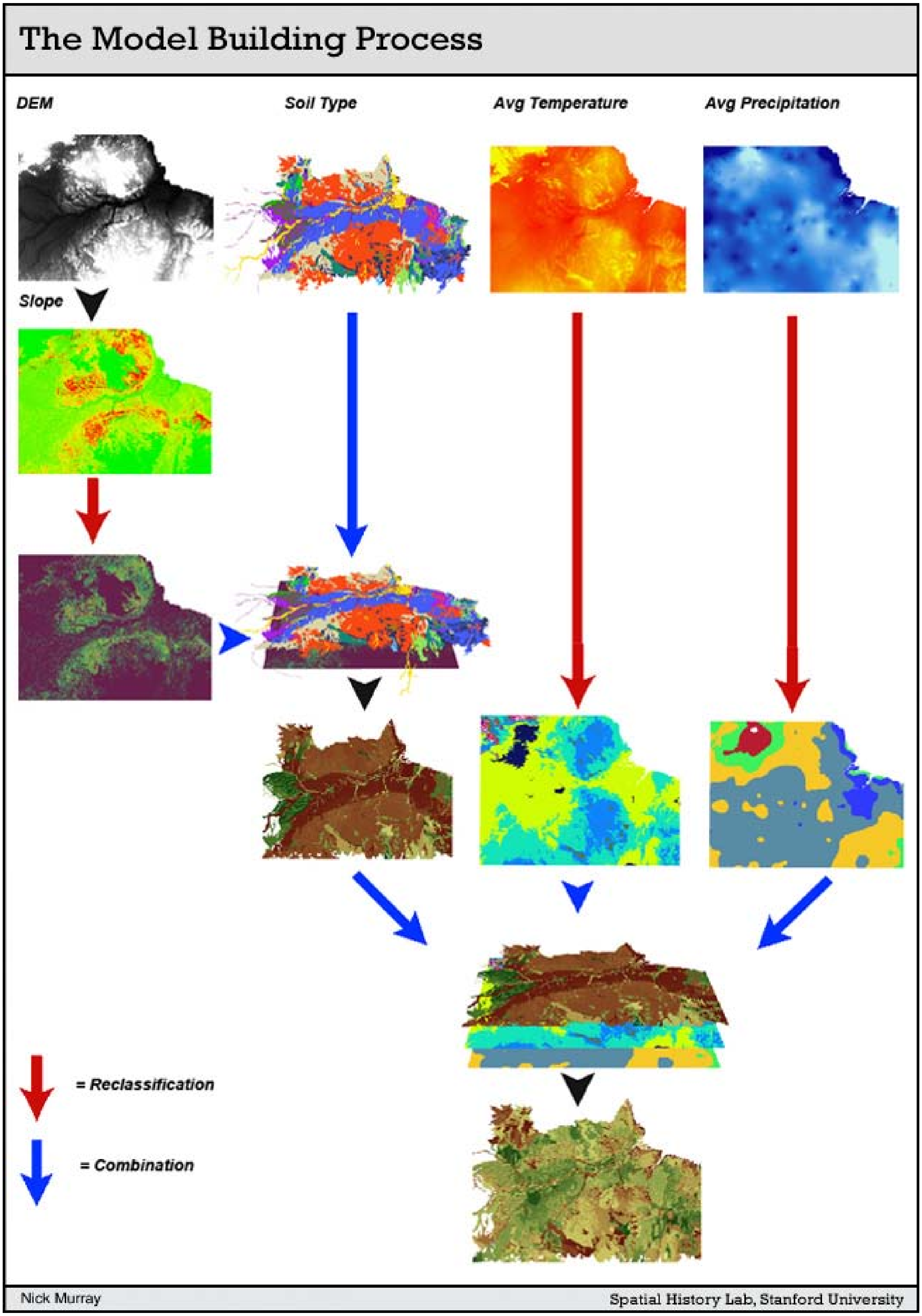
$$c_L = 0.5$$

$$c_T = 0.3$$

$$c_P = 0.2$$

Where S is the overall suitability rating from zero to ten, L is the land suitability rating, T is the temperature suitability rating, and P is the precipitation suitability rating. The c values correspond to the weights assigned to each variable. The finished suitability maps display the S dataset, displaying for each pixel of the study region a score between zero and ten. Finally a sliding color scale was applied to the pixel values of the entire map, so as to provide an accessible visualization of the agricultural suitability of the study region with respect to each subject crop.

Figure 4. The Model Building Process. **A visual representation of the process behind model construction. Processing raw data on elevation (DEM), soil type, temperature and precipitation yielded a unique suitability map for each target crop.**



References

Bydekerke, L., E. Van Ranst, L. Vanmechelen, and R. Goenemans. “Land Suitability Assessment for Cherimoya in Southern Ecuador Using Expert Knowledge and GIS.” *Agriculture Ecosystems & Environment* 69. (1998): 89-98. Web. 2 Jul 2010.

Cointreau, Anne Dorothee Mercier. “The Freedom of Owning Its Own Land: Dream and Realities of the Brazilian Landless Movement.” *Renato Janine Online*. (2003) n. pag. Web. 14 Oct 2009.

Ekanayake, G.K., and N.D.K. Dayawansa. “Land Suitability Identification for a Production Forest through GIS Techniques.” *Forestry & Biodiversity* (2003): n. pag. Web. 2 Jul 2010.

Geist, Helmut J., and Eric F. Lambin. “Proximate Causes and Underlying Driving Forces of Tropical Deforestation.” Bioscience 52.2 (2002): 143. *Academic Search Premier*. EBSCO. Web. 02 Feb. 2010.

“GIS: A Window on Tropical Agriculture and Natural Resources.” *CIAT in Focus: Crop Commitments 2001*: n. pag. Web. 2 Jul 2010.

Kalgirou, S. “Expert Systems and GIS: An Application of Land Suitability Evaluation.” *Computers, Environment and Urban Systems* 26.2-3 (2001): 89-112. Web. 2 Jul 2010.

Martins, J. de S. (1984). “The State and the Militarization of the Agrarian Question in Brazil.” in Frontier Expansion in Amazonia. Schmink, M. and Wood, C. University of Florida Press, Gainesville. 463-490.

McGinty, Meghan M., Mickie E. Swisher, and Janaki Alavalapati. “Agroforestry adoption and maintenance: self-efficacy, attitudes and socio-economic factors [electronic resource].” *Agroforestry systems* 73 (2008): 99-108. Agricola. EBSCO. Web. 07 Feb. 2010.

Mendoza, G.A. “GIS-Based Multicriteria Approaches to Land Suitability Assessment and Allocation.” *Seventh International Symposium on Systems Analysis in Forest Resources*. Traverse City, Michigan, 1997. Print.

Nepstad, Daniel, et al. “The End of Deforestation in the Brazilian Amazon.” Science 326.5958 (2009): 1350-1351. *Academic Search Premier*. EBSCO. Web. 04 Feb. 2010.

Negreiros, Gustavo. School of International Training. Tv. Pirajá, 1990. Marco. 66095-470, Belém - PA, Brazil. 07 Nov 2009. Address.

Pacheco, Pablo. “Smallholder Livelihoods, Wealth and Deforestation in the Eastern Amazon [electronic resource].” *Human ecology* 37.1 (2009): 27-41. Agricola. EBSCO. Web. 07 Feb. 2010.

Pattanayak, Subhrendu K., Evan Mercer, Erin Sills, and Jui-Chen Yang. “Taking Stock of Agroforestry Adoption Studies.” *Agroforestry Systems*. 57.3 (2003): 173-186. Print.

Pereira, José M. C.; Duckstein, Lucien. “A multiple criteria decision-making approach to GIS-based land suitability evaluation” International Journal of Geographical Information Systems 7.5 (1993). 06 Jul. 2010.

Smith, Nigel J. H. “Agroforestry experiences in the Brazilian Amazon: constraints and opportunities / by Nigel Smith ... [et al.].” *Conservation and development of Brazil’s tropical forest regions*. [Brasilia] : Pilot Program to Conserve the Brazilian Rain Forest ; Brasilia, D.F., Brasil; Washington, D.C. : World Bank, Rain Forest Unit, 1998., 1998. *Agricola*. EBSCO. Web. 04 Feb. 2010.

Yamada, M., and H.L. Gholz. “An evaluation of agroforestry systems as a rural development option for the Brazilian Amazon.” *Agroforestry systems* 55.2 (2002): 81-87. *Agricola*. EBSCO. Web. 07 Feb. 2010.

Crop Data References

Cowpeas

Soares de Andrade Júnior, Aderson. The Brazilian Agricultural Research Corporation (EMBRAPA). *Cultivo de Feijão Caupi*. Teresina, PI: 2003. Web. 11 Jul 2010.

Andersson, Meike. “Vigna Unguiculata (L.) Walp.” *Grassland Species Profiles*. 1st ed. Food and Agriculture Organization, 2010. Web.

Climate

Souza, Everaldo B., Marcio N.G. Lope, Edson J. P. da Rocha, José R. S. de Souza, and Douglas B.S. Ferreira. “The Rainy Season Over the Eastern Amazon as Depicted by REGCM3 Regional Simulations.” *Universidade Federal do Pará, Faculdade de Meterologia* (FAMET). (2007): Print.

Sweet Corn

Turner, Dianne. State of Queensland, Australia. Department of Employment, Economic Development and Innovation of the State of Queensland. *Growing Maize in the Coastal Wet Tropics*, 2010. Web. 13 Jul 2010.

Landau, Elena Charlotte. The Brazilian Agricultural Research Corporation (EMBRAPA). *Cultivo de Milho*. Teresina, PI: 2003. Web. 11 Jul 2010.

Andersson, Meike. “Zea Mays L.” *Grassland Species Profiles*. 1st ed. Food and Agriculture Organization, 2010. Web.

Manioc

Mattos, Pedro Luiz Pires. The Brazilian Agricultural Research Corporation (EMBRAPA). *Cultivo de Mandioca para o Estado do Pará*. Cruz das Almas, BA, Brazil: 2003. Web. 11 Jul 2010.

Watermelon

Dainello, Frank J. “Watermelon.” *Aggie Horticulture: Commercial Vegetable Crop Guides*. Department of Horticultural Sciences, Texas A&M University, Nov 2003. Web. 14 Jul2010.

Almeida, Domingos. “Melancia.” *Horticultura*. Universidade do Porto, 2003. Web. 12 Jul 2010.

Tupinambá, Maria José. “Cultivo Irrigado de Melancia em Terra Firme.” *AgroLink*. EMBRAPA Amazônia Ocidental, 20 Jul 2010. Web. 21 Jul 2010.

Melo, Paulo César. “Cultura da Melancia.” *Escola Superior de Agricultura*. Universidade Federal de São Paulo, 16 Jun 2005. Web. 14 Jul 2010.

AGLW Water Management Group. “Watermelon.” *Crop Water Management*. FAO: Land and Water Division, 16 Oct 2002. Web. 14 Jul 2010.

Okra

Turner, Dianne. State of Queensland, Australia. Department of Employment, Economic Development and Innovation of the State of Queensland. *Growing Okra*. 2007. Web. 13 Jul 2010.

“Okra.” *AgriHortiCo: Dissemination of Horticulture Information*. Agrihortico, 2010. Web. 10 Jul 2010.

Japanese Squash

"Clima e Solo." *Abóbora e Abobrinha*. Criar e Plantar, 2008. Web. 11 Jul 2010.

Lopes, José Flávio. "Produção de Abóboras e Morangas." *Unitins: Fundação Universidade do Tocantins*. Universidade de Tocantins, 2009. Web. 12 Jul 2010.

Acerola

Martins da Silva, Marcelo, and Maria Carmo Felipe de Oliveira. "Condições Agrometeorológicas em Cultura de Acerola em Castanhal no Estao do Pará." *cbmet.com: Congressos Brasileiros de Meteorologia*. Universidade Federal do Pará, 2009. Web. 16 Jul 2010.

Andrade Fraife Filho, Gilberto. Brazil. Comissão Executiva do Plano da Lavoura Cacaueira (CEPLAC). *Acerola*. Cruzeiro, DF: CEPLAC, 2010. Web. 18 Jul 2010.

Tahitian Lime

State Government of Bahía. Secretariat for Agriculure, Irrigation, and Agrarian Reform (SEAGRI). *Cultura de Limão Tahiti*. Salvador, BA: 2004. Web. 27 Jul 2010.

Fernando Alves, João. "Como Plantar: Limão." *GloboRural*. Jun 2010: n. pag. Web. 27 Jul 2010.

Urucum

Odel de Faria, José. State of Minas Gerais. Institute for Technical Assisstance and Rural Development (EMATER). *A Cultura de Urucum*. Belo Horizonte, MG: EMATER, 2000. Web. 20 Jul 2010.

Oliveira Franco, Camilo Flamarion. State of Paraíba. State Institute for Agricultural Reserach (EMEAPA). *Manejo da Cultura do Urucum (Bixa orellana L.)*. João Pessoa: EMEAPA, 2000. Web. 26 Jul 2010.

Mandarin Orange

State Government of Bahía. Secretariat for Agriculure, Irrigation, and Agrarian Reform (SEAGRI). *Cultura de Laranja*. Salvador, BA: 2004. Web. 27 Jul 2010.

"Laranja." *Agrov.com*. Católogo Rural. 2007. Web. 27 Jul 2010. http://www.agrov.com/vegetais/frutas/laranja.htm

Açaí

"Notícias: A Cultura do Açaí." *Toda Fruta: O Portal da Fruticultura*. TodaFruta.com.br, 2006. Web. 29 Jul 2010.

Muller, Antonio Augustino. The Brazilian Agricultural Research Corporation (EMBRAPA). *Sistema da Produção do Açaí*. Teresina, PI: 2003. Web. 11 Jul 2010.

Castanheira

Locatelli, Marilia. The Brazilian Agricultural Research Corporation (EMBRAPA). *Cultivo da Castanha-do-Brasil em Rondônia*. Teresina, PI: 2003. Web. 11 Jul 2010.

Bacuri

"Bacuri." *Portal São Francisco*. Portal São Francisco, 2007. Web. 24 Aug 2010. http://www.portalsaofrancisco.com.br/alfa/bacuri/bacuri.php.

Nascimento, Maria Oliveira. "Ocorrência e Distribuição Geográfica do Bacurizeiro." *Revista Brasileira de Fruticultura* 29.3 (2007): n. pag. Web. 12 Aug 2010.

Andirobeira

Rodrigues de Souza, Cintia. Brazilian Agricultural Research Corporation (EMBRAPA). *Documentos: EMBRAPA da Amazônia Ocidental*. Manaus: EMBRAPA, 2006. Print.

Taperebá

Bosco, João. State of Paraíba. State Institute for Agricultural Reserach (EMEAPA). *A Cajazeria: Una Alternativa para a Economia Regional*. João Pessoa: EMEAPA, 03 Jun 2003. Web. 26 Jul 2010.

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