# NEEM TREE ASSESSMENT FOR SOCIOECONOMIC EMPOWERMENT IN RURAL BURKINA FASO

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## ABSTRACT

The many uses of the neem tree (*Azadirachta indica*) include various health, pesticide, and soil amending applications (Kumar 2007, Lal 2004, NRC 1992, Norten 1996, Smith 1997), but as of yet neem is generally underutilized by certain Bissa communities of South-Central Burkina Faso, hereafter referred to as Moléntah (Pers. Obs.). This research aims to address informational gaps and, guided by the communities involved, facilitates community development of neem tree products for diversification of economic activity and improved quality of life. My master's project is thus based on work completed during the summer of 2009 in rural Burkina Faso, West Africa, where I worked in conjunction with local community members in Moléntah to raise the profile of neem as a useful natural resource.

The study was designed as participatory learning and action research to inform best practices for those community members interested in further pursuing neem production. The approach is based in the concept of broad-based, sustainable community development, emphasizing the interlocking nature of all sectors of life, now and in the future, as well as the importance of local participation in shaping processes according to knowledge of local assets, needs, and desires.

Together we inventoried the local neem resource base, identified market pathways, and piloted processes of seed collection and oil extraction. In so doing, we demonstrated the feasibility of utilizing the naturalized neem tree for socioeconomic activity with the potential to generate income in the area. Efforts around neem were met with general success despite some barriers, which include: conflicting accounts of best practices for processing neem, seasonal constraints on neem availability and community participation, and immature markets.

This work is significant on a variety of levels. Scientific inventories of neem trees and associated measurements are rare within the literature; this research thus provides a baseline from which future growth, yield, ownership, and usage patterns could be studied. The action learning process of piloting neem as a socioeconomic resource draws attention to constraints limiting development of neem not only in Moléntah but potentially in other developing country or rural settings as well. And most importantly, this work served to introduce the value of an underutilized natural resource to four villages; transferred capacity to recognize and build the local asset base; developed project planning and natural resource management knowledge and skills within Moléntah; and empowered enterprising participants to operationalize ecosystem services into productive socioeconomic potential.

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## INTRODUCTION

The people of Burkina Faso are known to be warm and welcoming, full of smiles and thanks. But their generosity often belies profound struggle – to eat, to obtain healthcare, to send children to school, to earn income, to make life more stable, a little bit easier. Vast potential is muted by the strain of day-to-day life.

The neem tree of India is hardy and full of biological potential, full of health and agricultural applications. But it mostly sits idle in South-Central Burkina Faso, aside from offering shade, wood, and the occasional toothbrush.

This research aimed to unlock the potential of neem within the communities of Moléntah[1], Burkina Faso, by introducing the value of neem and how to process it in order to increase opportunities to enhance quality of life. The project is based on work completed during the summer of 2009 in rural Burkina Faso, West Africa, where I worked in conjunction with local community members in Moléntah to assess the neem resource base as well as the feasibility of utilizing the naturalized neem tree to generate income. The study was designed as participatory learning and action research, meant to bridge informational gaps around neem and facilitate the community's desire, if any, to process neem for agricultural inputs or salable product.

The work was introductory and educational in nature, with the goal of diversifying economic activity by helping interested parties better understand their natural resource base and the market potential available via its processing. The myriad uses of the neem tree are largely unknown in South-Central Burkina Faso, and thus the tree is generally underutilized there; the disparity between actual and potential neem use in Moléntah motivated my work. I facilitated the conceptualization and utilization of neem as an economically useful natural resource in four neighboring communities, completing with them an assessment of neem as a potential driver of socioeconomic empowerment.

The following pages first establish the context for community development in Moléntah and then discuss the results of our initial effort to identify and process neem locally: an understanding not only of the baseline neem tree resource in Moléntah, but also of the community processes that shaped its use during this project. After framing the research in theory, geography, and method, the paper presents outcomes and insights from these community processes, relating to our inventory of local neem trees, the constraints we encountered in working with neem, community capacity built around neem, and the potential local value of neem processing.

[1] Moléntah is a pseudonym.

## Theoretical Perspective: Broad-Based, Sustainable Community Development

My theoretical perspective in approaching this work is broad-based, integrated, sustainable community development. I will dissect that terminology to elucidate assumptions implicit in my approach.

### *Broad-Based, Integrated Development*

The term development carries implicit assumptions and judgments regarding desirable progress (Kumar 2003), and has often been used synonymously with economic growth, largely modeled on industrialization. Over the years, its interpretation has broadened to account not only for increasing gross domestic product and productive capacity, but for equity and rights within the political economy. Broad-based development emerged, taking account not only of a growing and widely distributed economy, but also of effective governance and environmental preservation (Weaver et al 1997). Development came to focus increasingly on standard of living and quality of life in addition to economic productivity. Amartya Sen (1997) highlights these differences in distinguishing between the development of human capital – valuing people's ability to contribute to economic growth – and development of the more broadly defined human capability – those opportunities which enable people to choose a meaningful life. For example, education may provide value to someone's life, which is an end in and of itself, in addition to serving as a means for enhanced economic productivity. As such, Sen (1999) places humans, not economic growth, at the center of development, characterizing development as freedom – the opportunity to choose the life desired, with income and wealth as a means to that end.

I support this broader context for development, focusing on helping people attain the goals they seek for a 'better' life, which often include aspects related to basic needs such as food, water and shelter; education; health care; income generation; and social and political participation. Indeed I ascribe to the idea that each such segment of life is interlinked, and that a development solution remains incomplete until all are addressed, or at a minimum, are balanced. Thus development hinges not only on economic progress, but is based on a broad set of factors that influence human capability and opportunity.

Integrated development refers to development efforts that address multiple needs within the same project; most common are integrated conservation and development programs that are designed to address environmental conservation alongside human or economic development goals. Integrated development has been both criticized as no more effective than single-sector development projects as well as lauded for being more relevant and sustainable than single-sector approaches (Alpert 1996). I prefer to bypass that debate in favor of focusing on serving community needs in a way fitting the local context – often somewhat integrated, being based in life's complexities, but usually with a particular need at the core. A simple example: a farmer struggles to make ends meet. Cutting down trees to gain income may leave the farmer with cash, but with limited fruit and shade, and without revegetation, also with a degraded soil and a bleaker future. A more integrated scenario might incorporate natural resource management into small business development, to sustainably generate income through rotational timber or non-timber forest product harvests. A still more integrated scenario might both share financial management techniques to build wealth and incorporate preventive health strategies to reduce incidence of disease, plan pregnancy, and thus increase productivity of the entire family. Sometimes, crisis may necessitate intermediate, sectoral problem-solving, but community needs may be best met when development efforts recognize and address the multiple factors at play.

*Community and Participation*

The second term to consider then is community. Development takes place at many levels – from individual decision-making all the way to multilateral policy-making. Its goals range from earning one more dollar to ensuring basic needs provision and more equitable distribution of wealth and stability throughout the world, with means to those ends just as varied. Since development is a long-term, ongoing process, I perceive that all levels of effort can usefully contribute to the process. However, my work is focused at the community level, for the simple reason that a person's sphere of control is often most effective and exercisable in this space. While it may be attractive to wait for help from more powerful external sources – and indeed that potential dependency is a common criticism of development aid (Collier 1999) – a more proactive approach is community self-reliance, a concept promoted by Mahatma Gandhi (Kumar 2003). The possibility always exists that someone may not come from elsewhere to assist, so it is best to leverage local capabilities in the meantime.

These questions of dependency and empowerment lead me to combine an assets-based approach to community development with the traditional needs-based approach. All people are constantly making decisions about priorities; the difference for a struggling community lies in a more limited scope of resources that defines what can be prioritized. Of course external venues for obtaining investment support can often be identified, but a community has little control over those funders' current priority areas. Thus in order to foster independence and innovation beyond the scope of single development projects, I think it is important that any project helps local actors realize the power, resources, and assets that they possess and can make use of to approach goals that they have prioritized. I prefer a community-level approach to development, facilitating mobilization of community members' existing resources and skills, and helping them to acquire any necessary additions, in order to empower change from within (Uphoff et al 1999).

But community is not only relevant from the supply side of development – it is imperative to defining demand as well. It is, after all, the local people who have experienced and best know the local hardships, resources, and aspirations, who possess a "local theory" of how and why things are as they are in that context (Elden & Levin 1991). Thus development goals that emerge from the community, that are planned and implemented by or in partnership with the community, are most likely to be appropriate to that community's context. This approach is often called community-based development (Coirolo et al 2001), contrasted with 'top-down' development projects whose high-level origin can create difficulties in identification of priorities, alignment of incentives, or understanding of on-the-ground realities of implementation. My theory of change walks through the following steps: if the community identifies a development goal, and participates in planning and implementation, then the project is more likely to be appropriate in that local context and as such the development goal has a higher potential to be met over a longer term.

Participation is a key aspect of such community involvement in expressing demand for development efforts and shaping how that demand is met. Kemmis and McTaggart (2003) identify three attributes of participatory research that apply to participatory development: shared ownership of projects, community-based analysis of social problems, and an orientation toward community action. Full participation requires that beneficiaries be involved in all stages of conceptualization, planning, implementation, and evaluation. Some development projects are fully participatory; many incorporate participatory aspects, for example with donors, governments, or 'experts' proposing the sector or project focus, and community participation brought in to confirm need and shape implementation for the local context. High levels of participation require high levels of ethical responsibility on the part of project organizers (O'Leary 2005). Like the other concepts discussed so far, participatory approaches to development have both champions and critics. Participation is lauded for its inclusive focus, aiming to incorporate as many stakeholder perspectives as possible to shape problem definition and solution processes, for enhanced buy-in, empowerment, and project sustainability (Cleaver 1999). In some ways, participation has become a staple of development discourse, a response to top-down mistakes, a perceived panacea for how to create lasting social change (Cohen & Uphoff 1980).

But critiques abound, citing oversimplified assumptions of institutional effectiveness, cohesive communities, power dynamics, resource constraints, field implementation, and individual behaviors (Bowles & Gintis 2000, Cleaver 1999, Coirolo et al 2001, Khwaja 2004, Michener 1998). Participation itself is often simplified, whereas in reality it can take place on a variety of levels, via various methods, and contribute varying results to varying stakeholders (Uphoff 1992). There is a significant lack of empirical evidence to justify the broadly accepted claim that participation effectively achieves development outcomes (Mansuri & Rao 2003), with some studies suggesting decreased effectiveness and efficiency at least in some contexts (Khwaja 2004). The question remains: whether the participatory approach is inherently, conceptually misguided; or whether the flaw lies in appropriate implementation to date.

To be sure, participatory techniques do not necessarily yield sustainable solutions. Have we not all at some point failed to follow through on plans we designed ourselves with the best of intentions? Nonetheless, I believe strongly in incorporating at least some aspects of participation into development projects, lest development lose stakeholder input and risk becoming an industry unto itself: with only a common pool of development experts and resources, lack of external input and evaluation can enable justification of a potentially cyclic conceptualization of need, wherein development praises itself for providing 'assistance' that may or may not have been wanted, applicable, or even useful – and may even be counterproductive (Ferguson 1994).

*Sustainability*

Indeed participation is often considered a key component of sustainability, yet another aspect of my theoretical perspective subject to myriad interpretations. The various interpretations of sustainability could fill – and surely have filled – volumes. The term gained prominence through the UN Brundtland Commission's 1987 report (WCED 1987), which famously defined sustainability as

> "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

The following decades have yielded countless critiques, for example pointing out the subjective nature of need, along with innumerable interpretations and alternate definitions.

Understanding of sustainability tends to reflect the sector in which one operates. For example, there are early economic interpretations of sustainable development (Barbier 1987), along with current business interpretations of sustainability which try to shift from the profit bottom line to the 'triple bottom line' of 'people, planet, and profit' (Elkington 2004). Recent business-oriented sustainability focuses on corporate social responsibility, social entrepreneurship, and tapping the market potential of the 'base of the pyramid' (Prahalad 2006, Yunus 2007). The three-component interpretation of sustainability – balancing the environment, economy, and society – is widely accepted, but tends to sectoralize sustainability approaches (Giddings et al 2002). For example, environmentalists have often focused on natural resource and ecosystem management for environmental sustainability (Folke et al 2002), with less regard for formal markets (although this is changing with carbon markets and ecosystem service valuation). Sociopolitical interpretations of sustainability are also emerging, focused on citizen participation, governance, and equality, emphasizing social sustainability of systems (McKenzie

2004, Misiunas & Balsyte 2009). The concept of human development leads to an interpretation of sustainability based on the social ethic of universalism as applied to present and future generations – the power and opportunity for all to live meaningfully, today and tomorrow (Arnand & Sen 2000). Such a conceptualization might replace the 'profit' of the triple bottom line with 'prosperity.' A recent conceptualization suggests five dimensions of sustainability – temporal permanence, individuals, and the physical, geographical, and cultural dimensions of place (Seghezzo 2009). The plethora of sustainabilities tempts some to discount any useful concept the word might house, its utility lost in a 'quagmire of debate' or the necessity of constant clarification. However, some believe sustainability and sustainable development are still useful concepts (Hopwood et al 2005), particularly if the associated ambiguity and pluralism are embraced (Sneddon et al 2006).

I fall into this latter camp, failing to see why varying context-driven applications of sustainability would reduce its value or utility. All interactions occur in a context, and so the particular nuance of a given sustainability should be attainable from context, often without explicit clarification. But more simply, I find that the various definitions of sustainability are hardly mutually exclusive; they merely place different emphases. All are conveying the essence of the word – to sustain. As such, sustainability simply means to persist, to continue, to endure – which definitionally implies an indefinite timescale.

It is important to clarify the anthropocentric nature of sustainability from my perspective: I am generally concerned with the continuance of human life on earth, the human experience to date. The sustainability of the earth itself, or the universe, is less a concern to me than humans' ability to sustain our lives on the earth. That reflects my implicit assumption that the earth will likely survive as a planet longer than humans might survive as a species; that human demise would likely not explode or implode the planet[2]. So sustainability, to me, means to continue human life on earth. Sustainable development then is the effort to indefinitely meet basic needs for all of humanity on earth; sustainable development projects should address root causes to implement lasting systemic change. This involves both recognizing the interdisciplinarity and interconnectivity of needs, as well as acting in ways that maintain or even regenerate, rather than degrade or use up, environmental and human resources. As such, sustainability is as much a directional journey as a goal (Schroeder-Moreno 2008).

From the social perspective, development interventions must be integrated with local knowledge and context in order to be fully adopted (Horton 1991, Kumaran 2004). From the environmental perspective, mainstreaming discussion of the reliance that various sectors of society have on ecological contexts within which they operate can enhance communication and

[2] Although, as Crutzen (2002) suggests, the extent of human impact on the earth is at this point largely "terra incognita."

coordination to protect natural resources and ecosystem services (Aronson 2007, Bainbridge 2007). I find simplistic the Malthusian (and often narrowly environmental) perspective of population growth as the primary factor threatening the ability of natural resources to meet human needs. Though imperfect still, I prefer the I=PAT model, in which environmental impact is determined by the interactions of population size, affluence, and technology (Daily & Ehrlich 1992).

Behavioral choice is an important part of this conceptualization, impacting all factors and thus our ability to sustain on earth (Schulze 2002, Diesendorf 2002). As such, human sustainability on earth is very much our choice. I have characterized sustainability as the continuation of human life – for all – on our planet. Various interpretations of sustainability are sub-contexts. The main complicating factors then become questions of adequate human understanding, including of the role of the environment in keeping the earth livable, and ethical choices around equity and goodwill toward other humans (Daily & Ehrlich 1992) and the rest of the earth.

Combining these terminologies then, I have identified my theoretical perspective as broad-based, sustainable community development, with the associated contexts and assumptions explained above. What does this look like in action? Here is a brief summary to help establish context, with methods more fully discussed at a later point. Given my theoretical orientation, I approach development from the perspective of facilitation. I aim to catalyze activity, using my training, background, and access to resources to suggest possibilities, to foster a participatory approach to planning and implementation of development activities.

The interventions undertaken by a community would depend on their priorities and their multiple scales of consideration, both temporal and spatial (Aronson et al 2007). Action could be individually oriented, family oriented, community oriented, or inter-communally coordinated and regionally expanded. It could be a discreet, short project; a recurring seasonal project; a long-term investment focused on a single sector; or an integrated development program. As long as diverse and multiple stakeholders are involved from the initial stages of raising awareness through project design, implementation, management, and adjustment, development should succeed as a community-based process of catalytic, integrated change for the local good.

It is in this vein that I brought forward the potential of neem to Moléntah community members and worked with those interested to complete a resource assessment and pilot seed processing and oil extraction demonstration. Having transferred the primary skills and knowledge to a subset of the community, I then leave it largely to them whether they wish to pursue the activity further. I still offer informal reminders and continued availability should any questions or resource constraints arise, but the emphasis throughout is on facilitation of knowledge and skills transfer for community member capacity-building and ownership.

## Geographic & Cultural Context: the Bissa of South-Central Burkina Faso

This paper focuses on my recent effort to facilitate the conceptualization and utilization of neem as an economically useful natural resource to four neighboring communities, referred to here as Moléntah[3], in South-Central Burkina Faso. Rural Burkina is a fascinating case study for integrated community development, since the interdependencies among the state of the environment and natural resources, the limited local or national economic investment capability, and the social imperatives of basic needs provision are so evident and undeniable. Some geographical and cultural contextualization is in order.

### *Geography and Environment*

Burkina Faso is a landlocked country comprised of more than sixty ethnicities, situated in the heart of the West African Sahel. Generally included amongst the poorest countries in the world (World Bank 2007), the vast majority of the population relies on subsistence farming, particularly in rural areas. However, agriculture is not an easy task in Burkina Faso, as poor infrastructure as well as poverty and population pressures exacerbate already difficult climatic and pedological conditions (Burkina Faso Atlas 1998). For example, sporadic rainfall and locusts caused severe crop loss in the northern part of the country in 2004; flooding caused significant crop loss in both the north and south, including Moléntah, in 2007; and wind caused near complete loss of the main cereal crop in Moléntah in 2009 (Pers. Obs. and Comm.). Heavy showers, high winds, topography and human degradation of vegetation make wind and water erosion a concern.

The area of Burkina Faso in which Moléntah is situated is characterized by low-input, subsistence farming in the natural environmental context of woody savannah vegetation, flat topography, and semi-arid climate, having unimodal rainfall of <1000 mm annually (NRC 1984, Seaquist 2003). Major crops around Moléntah include peanuts, sorghum, millet, maize, rice, black-eyed peas, cowpeas, and assorted leaf vegetables and tubers, all grown with limited synthetic inputs such as agrochemicals, primarily due to lack of financial resources (Pers. Obs. and Comm.). Yields are generally enough to feed a family for the majority of the year, with poorer families taking grain loans from more well-off families for next year's seed, and in hard times, for food during the last months of the dry season and the first months of the rainy

[3] The author completed two years of Peace Corps service and completed a summer internship in the Moléntah area during the decade preceding the neem research described in this paper. See Methods section for further discussion of the effect on research of researcher-community relationship.

season until the first harvest (Pers. Obs.). Soil fertility in the country has been declining (Sawadogo 1997), suggesting a 'downward spiral' of both natural systems function and agricultural productivity.

*Socioeconomic Characteristics*

The primary ethnicity in Moléntah is Bissa, comprising approximately 7% of the Burkinabé population. The Bissa are a Mandé people present in the area for 700 years[4], currently well-known for their peanut farms and established presence farming tomatoes in Italy. The Bissa live around the Bagré reservoir, which provides fish and enables vegetable, bean, and peanut production; these food sources surely help to reduce malnutrition in the region.

In Moléntah, the economy is based on subsistence farming. Men are generally considered responsible for the family's overall food and economic security, farming fields alongside other family members. Each wife will also have her own field, to enhance her income generation for expenses related to food preparation, household/personal items, and childcare (Pers. Obs.). In search of additional income and sometimes in response to limited land access, many young Burkinabé men emigrate, for example to Côte d'Ivoire, often working on cash-crop farms or as cooks.

The Bissa in particular have a significant tradition of emigrating to work on tomato farms in Italy, which provides an historical flow of significant income back into the region even while incurring some social costs. Indeed, in the Bissa towns that first established connections in Italy, one can see clear signs of wealth in cement houses – some of them two-story. Unfortunately, it is also in those towns where I saw a startling lack of trees and erosion of soil. This environmental degradation does not have to be a given, however, since rainfall and growing conditions tend to be fairly stable in this area (Burkina Faso Atlas 1998, Pers. Obs. and Comm.). There is a great opportunity to shape development and increasing prosperity toward a sustainable path for the Bissa of South-Central Burkina Faso.

Most adults in Moléntah have no formal education, with approximately 10% speaking French, while the rest speak the local language of Bissa. Some have attended Bissa literacy and numeracy training schools. Children are increasingly enrolled in primary education, however most do not continue past primary school and have minimal working knowledge of French. Most children attend Quranic school before beginning formal education, while others continue Quranic school instead of entering the state school system (Pers. Obs. & Comm.)

Moléntah is predominantly Muslim, and polygamy is widely practiced, particularly when a man is socioeconomically able to support an additional wife and children. Most women have six to

[4] McFarland, D. Historical Dictionary of Burkina Faso. Lanham, MD: Scarecrow Press. 1998.

eight pregnancies and have lost at least one child (Pers. Obs.). Daily life, social interaction, and associated workloads follow strong gender norms, for example with women and girls collecting fuelwood and water while boys tend livestock. Every third day there is a market serving surrounding areas at which some men operate small general stores, repair stands, and tailoring services, while most women sell a food product – cultivated, gathered, or prepared – such as seeds, cakes, rice or fish. Some of the products sold at market are initially obtained through collective buying arrangements of community groups. (Pers. Obs.)

Community members of Moléntah live a very modest lifestyle in large part due to the limited and inconsistent agricultural yields from the sparse and variable natural resources upon which every family depends for its main household subsistence. With the population growth rate high and agricultural practices fairly stagnant, fields are extending further away from homes into outlying lands *en brousse* and are left fallow for shorter periods of time, while emigration remains an economic reality (Burkina Faso Atlas 1998, Pers. Obs.). Although residents possess extensive observation- and experience-based knowledge of local agriculture, there is generally a lack of scientific understanding of environmental processes or the ecological impacts of farming systems.

*Agroecological Resource Management*

The complexity of environmental and social factors influencing Moléntah's societal landscape gives rise to equally complex socioeconomic effects that require broad-based development approaches. As described above, for interventions to be readily implemented, they must stem from resources readily accessible to the community: their labor, time, and natural resource base augmented with appropriate technologies. The community must be at the heart of any decisions, as they will be the ones implementing the interventions (Kumaran 2004). While the Moléntah area is generally underserved by NGO or governmental extension services, the area experiences relatively amenable environmental conditions and possesses other existing assets that indicate significant potential for supporting livelihoods and communities in the region (Pers. Obs.). In fact there are several approaches that are within the Moléntah resource-base control, and that could serve as initial infrastructure for stabilizing environmental impacts and resources, and thus livelihoods.

One approach to managing local agroecosystems for socioeconomic-ecological balance is through native tree agroforestry techniques, which can be introduced as an immediately accessible, low-input management intervention simultaneously impacting agricultural productivity, ecosystem health, and community income (Teklehaimanot 2004). Agroforestry can be defined as purposeful inclusion of multipurpose trees on cropland and can occur on spatial/simultaneous (i.e. windbreaks in fields; mixed or row/strip cropping) and temporal/sequential (i.e. crop-fallow rotations; planting for staggered maturation) scales

(Rhoades 1997). In the Sahel, agroforestry traditionally occurs as parklands, or scattered trees incorporated into agricultural fields or fallows (Teklehaimanot 2004, Erdmann 2005), and can play a critical role in enhancing soil productivity through enhanced nutrient availability and erosion control (Mayus 1999, Ouédraogo 2006, Kessler 1991 & 1992, Bokary 2007).

Agroforestry trees are chosen for socioeconomic value, but often they may serve environmental purposes as well, for example augmenting the microclimate around the edge of the canopy and beyond or contributing leguminous leaf litter in some cases (Huxley 1985). Many agroforestry trees, particularly native trees, are readily available to be planted, are suited to the harsh environmental conditions, and provide a variety of benefits such as food and the ability to be trimmed for fuelwood (Teklehaimanot 2004, Bayala et al 2007). In addition, native tree seeds are readily available and do not require extra investment for local people to gain access. A key example of a traditional agroforestry crop is the shea nut tree (karité), which provides a nut processed for oil used in West African cooking as well as for cosmetic application. In fact, in southern Burkina Faso, the tree is fostered by traditional land-use patterns, and women, who traditionally gather and process the shea nut, are realizing a burgeoning new income source as worldwide markets increase demand for shea nut butter (Elias 2007). However, agroforestry should not be promoted to the detriment of food crops or depletion of groundwater levels – perhaps this is one reason why Sahelian farmers have traditionally fostered parklands as opposed to permanent tree cover and why traditional practices such as soil manipulation, e.g. through planting basins (*zaï*), have included efforts to direct water away from bare soil towards agroforested trees or crops (Smith et al 1997, Franzel et al 2004).

This paper focuses on understanding the naturalized neem tree, *Azadirachta indica*, as a highly sustainable and immediate option for augmenting socioeconomic and agroenvironmental stability in the Moléntah area. Utilization of neem is a small step that local communities could potentially undertake now to foster agroecological balance, generate income, and sustainably shape their own futures.

## Neem: Tree of a Thousand Uses

I first heard of the neem tree, botanical name *Azadirachta indica*, in the development context as a potential ingredient for cottage industry soap-making. In fact, neem is originally from India and was brought to West Africa in the 1920s, arriving in Moléntah via Ghana (NRC 1992, Pers. Comm.). Neem is naturalized throughout much of the tropics; its wide geographic distribution is in part due to its ability to grow quickly, rooting deeply into a variety of soils (ideally sandy) and for its notable persistence under harsh conditions such as drought, high temperatures, and high soil acidity (NRC 1992, Smith 1997, Lal 2004). Neem grows quickly after the first year, reaching maturity in ten years with a straight trunk up to 30 meters tall and 1 meter across and a dense, rounded crown up to 20 meters wide (NRC 1992, Norten 1996, Neem Foundation 2008).


Neem tree with fruits, flowers, leaves, seeds

Neem has been planted at Mecca (Ahmed et al 1989) for shade and is often used as a shade tree and wood source in African communities (Ciesla 1993, Förster & Moser 2000, Obara et al 2004, Nanang et al 1997, Pers. Obs.); however, neem's utility far exceeds these common uses. Neem has been used for thousands of years as a homeopathic cosmetic and health aid (Sharma et al 2007), with both traditional and scientifically proven antibacterial, antiviral, anticancer, antimalarial, contraceptive, and dermatological applications (Subapriya & Nagini 2005, NRC 1992, Norten 1996). In addition, neem can be used as a natural soil amendment or biopesticide to maintain agricultural yields with fewer synthetic inputs, in water and land remediation, for timber, for nutrition, as well as in various industrial processes (Yadav & Tarafdar 2004, Agbenin et al 1999, NRC 1992, Puste et al 2005, Sithisarn 2007, Norten 1996, Ahmed & Grainge 1986).

The neem tree is useful in many contexts; notably each of its parts is also useful: bark, wood, leaf, flower, fruit, seed kernel (also called cake or residue), seed oil, and extracted compounds (Radwanski & Wickens 1981, Biswas et al 2002, Tewari & von Gadow 2005). Note that the method of extraction has implications for quality of neem seed oil. Leaves are considered the most sustainable and easily accessible neem resource, particularly in areas where the typical evergreen sheds leaves annually, followed by fruit/seed including extracted oil, and then bark/wood, which can often be sustained through pollarding or coppicing (Tilander et al 1995, NRC 1992, Norton 1996). In addition, 150-300 compounds have been isolated from the neem tree. Some of these extracted compounds, as well as endophytic fungi and actinomycetes, have been evaluated for potential applications in health and agriculture (Biswas et al 2002; Atawodi & Atawodi 2009, Verma et al 2009). It is the complex structures and interactions of neem compounds that give rise to neem's variety of uses – and which have so far precluded its complete synthetic replication.

Over the last 30-40 years neem has received waves of attention in western scientific research, but it is still remarkably unknown in much of the world, the details of how it functions still largely shrouded in mystery (FAO/INN 2007). In the 1980s-90s neem garnered significant attention as a key component of a continuing green revolution, with the National Research Council devoting resources to discovering neem and several neem conferences focused on exchanging information and expertise to facilitate development of the natural resource, dubbed "neem-mania" (Stone 1992). Indeed the majority of neem research has focused on agriculture applications, generally with neem as a bio-pesticide alternative to chemical pesticides that can harm both humans and the earth, or as an amendment to enhance soil fertility and thus increase crop yields and the sustainability of agriculture. For example, decades ago, neem leaf chemical composition was analyzed and neem seed cake compared to various forms of manure, with the goal of enhancing soil fertility (Radwanski & Wickens 1981). More recently, direct health treatments and outcomes related to neem have been researched, with medicinal uses outlined above (Atawodi & Atawodi 2009, Subapriya & Nagini 2005, Biswas et al 2002, Sharma et al 2007).

Thus neem is a promising natural resource for impacting the state of the world's agriculture and health, with research suggesting powerful biopesticide and soil quality applications in addition to cutting edge anticarcinogenic activities, water quality remediation, malarial vector disruption, contraceptive effects in addition to basic dental, fever, and skin applications (Isman 2006, Uyovbisere & Elemo 2002, Tilander & Bonzi 1997, Tran & Perry 2003, Srivastava et al 2008, Boeke et al 2004, Subrapriya et al 2004, Bhattacharyya & Sharma 2004, Gianotti et al 2008, Botelho et al 2008, Khillare & Shrivastav 2003, Brahmachari 2004). Authenticating these uses through information sharing, further research, and training in best practices of neem processing and application would help to build the potential neem market. This in turn would increase accessibility of neem products and directly address current issues of environmental inequity around healthcare, food accessibility, and economic development in poor regions of the world.

There are few resources left unused in Burkinabé culture – crop residues feed livestock, tree fruits are harvested for fruit and oil, a variety of wild plants are the base of edible leaf sauces. But neem seeds simply fall to the ground and decay, occasionally sprouting a seedling. Indeed, each unused part of the neem tree represents a foregone opportunity for the world's poor not only to access effective medicinal treatment and crop applications, but also to build cottage industry based on sustainable use of local natural resources. Emanating from knowledge of the numerous traditional Indian uses for neem, the opportunity becomes palpable to transform rotting seeds into health products, agricultural yields, and income in Burkina Faso; this opportunity motivated the work described herein.

## METHODS

This research project was designed as participatory learning and action research and involved semi-structured community group interviews, participant-observation, conversation analysis, as well as forestry field work and limited contextual market research. I will first discuss the qualitative perspective and methods before presenting the forestry measurement methods utilized.

### Key Concepts in Qualitative Research

#### *Towards a Definition*

Qualitative research emerged from German interpretivist philosophies of the late 18$^{th}$ to early 20$^{th}$ centuries, from the writings of Kant, Dilthey, and Weber, who challenged positivist thinking on the observability of fact through the scientific method, instead emphasizing human interpretation of events as knowledge that transcended empirical enquiry (Snape & Spencer 2003). The Chicago School is largely credited with cementing qualitative methods in early 20$^{th}$ century U.S. sociology and anthropology, although the strengths and criticisms of scientific method vs. qualitative approaches were still much debated into the late 20$^{th}$ century (Denzin & Lincoln 2003, Snape & Spencer 2003). Qualitative research has become widely established primarily in the last few decades across the social and behavioral sciences, and sometimes even the physical sciences. It stands in contrast to quantitative research, focusing not on objective scientific method or measurements of frequency and variable correlation, but on social processes and meanings, on the situational constraints and researcher roles that shape scientific inquiry (Denzin & Lincoln 2003). Utilizing varying methods, qualitative research is generally considered a naturalistic, interpretative, and information-rich approach, which places emphasis on representing participants' perspectives and uses a flexible research design to allow for interactive development and exploration of emergent issues (Lewis 2003, Snape & Spencer 2003).

*Researcher as Participant-Observer*

Any researcher operates within the limits of perception; qualitative research does not shy away from the researcher's potential impact on research implementation or reporting, perhaps because of the direct role researchers often take in understanding social contexts. Participation by the researcher is inherent in most research studies at some level, but the qualitative researcher is involved first-hand in the social setting of interest – acting as participant and observer. This study is no exception, with my role as participant observer being to facilitate neem assessment and processing even as I documented the nuances of those community processes. Participant observation is considered both an overall approach to inquiry and a method for data collection in qualitative research (Marshall & Rossman 1995).

As such, the role of the researcher and researcher-community relationships are important components of qualitative research. Historically, researchers were expected to maintain a personal and professional distance throughout fieldwork, even as the interpersonal nature of fieldwork relationships was recognized (Atkinson et al 2003). Atkinson et al (2003) argue that fieldwork is "relational, emotional, and personal" with the researcher playing a central role within, and being affected by, the complex social situation under study. The term reflexivity is often used to denote the attention that must be paid to the researcher's place within the social fabric being studied, including issues of interpersonal relationships; reciprocity; power differentials vis-à-vis those being researched; ethical standards of confidentiality and consent; and any effect the researcher may have on the research process, outcomes, or analysis, in addition to ways in which these factors may in turn influence the researcher (Lewis 2003, Haney 2002, Yin 1994).

*Acknowledgement of Relationship with Moléntah Community*

My role in the communities of Moléntah is not that of stranger, nor that of full immersion. I completed two years of Peace Corps service in the Moléntah area, with joint goals of cultural exchange and technical assistance in the areas of preventive health and sustainable community development. Thus I have fairly extensive day-to-day experience living in Moléntah and interacting with its residents. I have various relationships, from professional colleagues and partners to acquaintances, friends, and local 'family'. These relationships have been furthered via telephone contact from abroad and a two-month return to Moléntah during the summer of 2008. I am committed to the people of Moléntah and am a recurring feature in Moléntah, and yet I remain the honored foreigner, as strangers are typically treated in Burkinabé culture. The personalized nature of my relationships in Moléntah enables trust and community access that may be more difficult for a stranger to garner (Lewis 2003); but my work is also impacted by local politics that a first-time visitor to Moléntah might not be subject to, or at least might not notice. In addition, perceptions – both positive and negative – of my past work and interactions surely impact community members' willingness to participate in subsequent activities that I facilitate. My role in the community also impacts how I conduct and evaluate my research activities; while I aim to be inclusive and collaborative, I surely have trouble perceiving the ways in which my presence shapes people's decisions, particularly as they differ when I am present to when I am not. Overall, I am confident that this relationship with Moléntah fosters my ability to work there effectively and instead of preventing me from observing social processes in a rigorous way, enables me to bridge community and scientific perspectives (Ruano 1991).

## Tradition of Inquiry: Action Research in Case Study Context

### *Action Research*

In aiming to work with the community to actively address the fundamental issue of poverty, this research into neem's local context can be classified as action research in a case study context. The concept of action research arose in the 1940s as a practical, organization-based problem-solving research response emphasizing relevance to expert-led, objective scientific research emphasizing rigor for the sake of furthering knowledge (O'Leary 2005, Argyris et al 1985, Kemmis & McTaggart 2003, Elden & Levin 1991). According to O'Leary (2005), action research uses collaborative approaches to address real-world problems, with an iterative cycle of experience- and knowledge-based action to continuously improve situations. Action research is bounded by the local practice context (Argyris & Schön 1991), where action scientists thus attempt to answer not only 'what is happening?' but also 'how can that be transformed?' (Argyris et al 1985).

Kemmis and McTaggart (2003) characterize action research as building from gaps in participants' actions (theories-in-use) and words (espoused theories) – with the differences serving as fulcrums of change in organizational practice, assigning responsibility to participants for having chosen a particular action (Argyris et al 1985). The associated cycle of changing actions to improve practice implies that action research is longitudinally designed, and generally consists of a series of research projects, each built off of previous learning.

Those affected by the situation being researched are in varying ways and to varying extents participating in shaping the research process, generally facilitated by the researchers themselves. Since decisions are collective, the ultimate direction that action research will take is only partially controlled by the researcher – thus flexibility is key (O'Leary 2005). Action research often draws upon localized knowledge of participants, recognizing how stakeholder engagement and ownership can contribute to making change effective and sustainable (O'Leary 2005). Action science not only seeks to build from participants' perceptions and behaviors, but also contains an element of skills transfer, seeking to instill in participants the desire and know-how to implement the action research cycle for continuous improvement (Argyris et al 1995).

While action research generally includes participatory aspects, it is differentiated from participatory action research (PAR), often utilized as a community development technique, by a more flexible extent of participation and origination of action plan. While action research maintains a separation of intervention/observation team from participants in order to document the learning process that leads to new courses of action (Whyte 1991), PAR focuses on participant ownership and generation of inquiry (Argyris & Schön 1991). Elden and Levin (1991) describe PAR as a "learning strategy for empowering participants," emphasizing participant insight gained through examining the social context, enhanced capacity to learn, and liberation through formulation of new paths to action. Some identify PAR's commitment to marginalized people by enhancing their capacity to "capitalize on capabilities and cultural practices… to generate knowledge and action from their own perspectives, and in their own interests" (O'Leary 2005). To achieve this empowerment, participants must be co-creators of knowledge – the community itself must come up with the problem to solve and the know-how to do so, must be fully integrated in and driving all steps of research from problem definition through to evaluation (Elden & Levin 1991).

This study is grounded in the action research tradition, serving as the initial cycle of neem processing that is intended to inform subsequent seasons' efforts. Smaller steps of this study's approach were also refined for improved implementation within the study period described here; for example, inventory documentation evolved in the field and seed weighing became progressively smoother based on lessons learned at previous households. The entire project was designed to be flexible and emergent, responsive to the interests and needs of Moléntah community members. This initial endeavor into neem in Moléntah was a collaborative, hands-on approach to addressing the need for income and agricultural inputs – defined by local personalities, participation, constraints, and context – to see how neem might 'work' there, and how to strengthen the process along the way.

### *Case Study*

The defining characteristic of a case study is perhaps its singularity: it is limited in space and time (Hamel 1993) and is designed to capture the complexity of a particular, specific situational context (Lewis 2003, Stake 1995 & 2003). Case study has traditionally been characterized as exploratory – an initial instrumental step in understanding something broader than that particular case, perhaps even informing theory (Yin 1994, Stake 1995). It is not meant as a sub-sample of activities common throughout society, but as a source of potential theoretical insight into how societies function. Yin (1994) states:

> "[In attempting to] understand complex social phenomena… the case study allows an investigation to retain the holistic and meaningful characteristics of real-life events."

Thus a major strength of case study is its allowance for the complexity and variable nature of social behavior (Lewis 2003) in seeking to answer societal questions of how and why (Yin 1994). However, not all case studies are purposed for generalization: intrinsic case studies are instead motivated by the desire to learn about that particular context (Stake 1995 & 2003). Action research and intrinsic case study may thus dovetail nicely, using real-life understanding to improve specific situations, for example the potential of neem in the Moléntah context.

Indeed this research is appropriately described as a case study, as it was bounded by Moléntah's geography and three months' time. Further, it is primarily intrinsic, designed less to generalize about community development of neem in any rural area and more to uncover the complexities, discover the variability, and learn how an effort to process neem in Moléntah would – or could – unfold.

## **Qualitative Data Collection**

### *Theory & Methods*

I used a mixed method qualitative approach[5] combining semi-structured group discussions, observation, and conversation analysis to gain historical, strategic, operational, and motivational insight into neem's context in Moléntah. I chose semi-structured group interviews to clarify an appropriate starting place for the research on neem, and moved to primarily naturally occurring participant-observation and conversation analysis once neem processes were in progress.[6] Observation allows for direct information gathering on behaviors, while

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[5] For further discussion of mixed methodology to fulfill various research functions, see Ritchie 2003.
[6] For further discussion of data collection method choice, see Lewis 2003.

interviews can uncover past experiences, perceptions, and incentives: the two techniques complement one another in elucidating social processes (Gerson & Horowitz 2002) and help ensure validity (Yin 1994). For this research, group discussions were important in reaching a common understanding of how the proposed research to raise the profile of neem should be structured, ensuring a workable fit with perceptions about neem and income generating activities, as well as with any past activities involving neem.

Once the action plan for the research was decided, observation became the primary method to understand the social process as it was unfolding. Participant-observation methodology refers to "data gathered by the researcher being present, and participating in the activities of the subjects under investigation; directly observing them and the other social phenomena relevant to the research question" (Sánchez-Jankowski 2002). Because action research includes a period of observation, reflection, and planning to inform the next cycle of action – and because a key tenet of sustainable development involves empowering the community to own its process of change in order to continue it into the future – I chose observation as a relatively unobtrusive method of data collection during the action phase. Thus while I was still participating alongside the community in certain activities, or catalyzing community participation through repeated inquiry, I observed what happened, rather than asking for others' perspectives on what and why things were happening. Gerson & Horowitz (2002) point out this interactive and flexible strength of qualitative strategies, which allow the weaving together of theory, method, insight, and design in a constantly defined research tapestry.

Note that a fully participatory action research project would likely have utilized focus group discussions to synthesize all stakeholders' observations and perspectives in order to shape future planning and action in an ongoing and transparent way. I prefer to introduce more fully participatory techniques once the community has begun to own the process, e.g. after the pilot stage, to assist in shaping the first community-driven replication of the transferred skills/knowledge around neem processing. Emergent themes, in this case from my participant-observation, have thus been incorporated here into recommendations for future action, to be shared with the community to inform their next efforts at neem processing, which may or may not involve me as a participant.

*In Practice*

I conducted semi-structured group interviews to assess existing knowledge, attitudes, and practices around neem; to discuss potential socioeconomic uses (e.g. soap making, soil conditioner) of neem byproducts; and to assess the willingness of community groups to engage in and organize for neem processing.[7] Each meeting followed a standard structure to discover

[7] See Appendix A for examples of semi-structured interview questions.

existing experience with neem; introduce the possibility of its agricultural and economic utility; and establish the basic framework for assessing the amount of neem available in the village and for gathering seeds in order to pilot oil extraction at the end of the summer. Community member focus group discussions (organized by community group or neighborhood) took approximately an hour. I worked in French with translation into local language, and responses were translated from local language to French (if they were not already in French).[8]

Village leaders were approached to ask for their support in organizing an informational meeting about neem in each of four villages (referred to herein as Apalko, Wasanti, Renyone, and Vondugu); all were in favor. All residents were invited to these initial meetings explaining neem in a socioeconomic context and assessing community interest. Residents were invited through (oral) announcements at market, through community group engagement, and through contact with village leaders such as chiefs, representatives, elders, and imams. Because the vast majority of the subjects cannot read or write, an oral consent process was used for interviews, emphasizing the voluntary nature of the gathering and active participation in it, the desire for input and feedback, and the research context.

Because there was no compensation for participation in group meetings, coercion was less likely. In addition, only the phrase *potential* income generation was used, with an emphasis on informational learning and pilot demonstrations, to minimize coercion, as well as simple premature augmentation of hopes for economic benefits. Cultural issues, such as potential gender-based or familial pressures not to participate, were beyond my purview to intervene in (or likely even to find out about). However, I attempted to include as many participants as possible by operating through neighborhoods as well as community groups, which are often intentionally gender divided by the communities themselves, enabling frankness of speech about such cultural issues as well as differences in opinion on approaches, practices, etc. Given the newness of the topic and the agricultural season, participation was likely reduced to 'early adopters' or those with personal reasons or financial capability to participate (instead of farm).

Towards the end of each introductory meeting, interest in participating in neem pilot activities was verified; community members were charged with selecting two literate youth, one male and one female, to join me in inventorying the neem tree resource base; and potential participants in neem seed processing were reminded that our next meeting would take place in 4-6 weeks to weigh collected neem seeds, after which we would work together to extract oil. An appointment was made for me to meet with the youth to begin measuring trees for the inventory, thanks were given to all, and we parted ways.

[8] The author can communicate day-to-day in local Bissa language, but is not professionally proficient.

Those interested and able collected neem seeds over the next several weeks and were invited to participate in a collective pilot demonstration meeting to hand press seeds for oil. To understand how seed collection activities were progressing, I made formal inquiries to community organizers and participants periodically. I also listened to or engaged in informal conversations taking place at market, while surveying neem tree prevalence, and in daily life. I gathered observational data on the processes of seed weighing and oil extraction, supplementing the latter through further discussion with key participants.

To understand potential market pathways for neem, I inquired with community members, foresters and merchants to gain understanding of the existing and potential market experiences they had had or heard of regarding neem in Burkina, from local and regional to national and international levels.

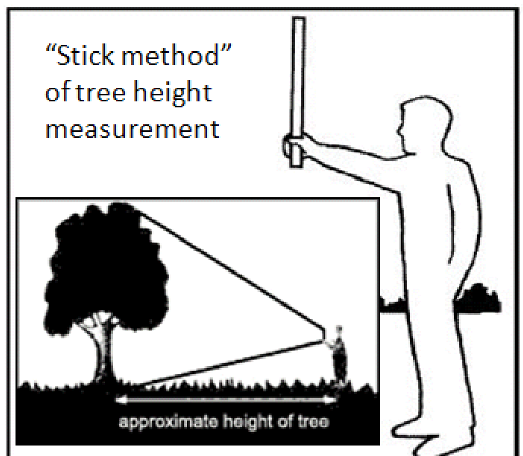
**Quantitative Forestry Methods**

I trained and worked alongside local community members to analyze neem tree prevalence (location, number and characteristics of existing trees) using all local materials aside from a GPS unit. This involved gathering GPS coordinates, circumference at breast height to determine diameter at breast height (DBH), crown width, and owner for all neem trees in four villages, as well as height, physical context, distinguishing characteristics, and reported age for select trees. I used a regression to complete the height dataset, based on partial height data gathered in Moléntah (65% of neem trees' heights were measured, primarily in Wasanti and Vondugu); I chose not to complete age data from secondary literature sources due to geographic variation in growth rates (Obara et al 2004, Nanang et al 1997) and paucity of reliable age estimations available from Moléntah neem owners.

Surrounded by a rice crop in Vondugu, field assistants use locally available materials to measure girth, crown , and height of a neem tree.

After each introductory neem meeting, an appointment was made for me to meet with community-selected youth, one male and one female capable of writing in French, to begin an inventory of neem near households and surrounding fields. Thus I trained 2-3 field assistants in each village to find, measure, and record neem tree data. We also developed a short briefing on the context of our work, explaining to residents the above measurement techniques as well as the key points of seed gathering: harvesting seeds that have fallen to the ground; keeping seeds from different trees separate if possible; rinsing the fruit pulp off; drying rinsed, depulped seeds in the shade to maintain chemical integrity and avoid mildew/fungus. Another meeting would be set up 4-6 weeks later to weigh the seeds, after which we would work together to extract oil. Thus our village field teams moved from house to house and field to field, reiterating information about neem uses along with how to gather neem seed in order to conserve its biochemical integrity, and encouraging people to gather seeds as possible to join in a collective oil pressing pilot demonstration at the end of the summer. Together we identified and measured all neem trees relatively near the villages[9], completing a baseline inventory of 744 neem trees over approximately 350 hectares – a fairly sizable, accessible resource in this area.

I emphasized the use of local materials in order to reveal local capability to conduct research and gather scientific data, and particularly to demonstrate the utility of school in positioning youth to lead such efforts in the future, for school projects or in collaboration with local forestry agents. A hardy twine was used for linear measurement, marked with locally available tape and later measured with a tailor's measuring tape. The stick method, depicted at right, was used for height measurement, which as the name implies, requires only a stick, along with the string distance measurement. While a chain, surveying tape measure (which was available through agricultural and forestry extension), or clinometer may have been scientifically preferable to twine and a stick, the research would not have been replicable, skills not transferred to the local context, had these external tools been brought in.



Sources: Americanforesters.org & Arkansas Envirothon and University of Arkansas Extension, uaex.edu

[9] Each village decided to inventory neem trees near homes and adjacent fields, and to exclude any neem trees *en brousse* for two reasons. First, they believed most neem trees were not located *en brousse* and so an accurate result would be obtained. Second, they believed any neem *en brousse* would likely not be included in seed gathering activities, as the displacement costs would not be worth the returns; thus these trees were not relevant to development of socioeconomic potential, due to their inaccessibility.

## Data Analysis

The data collected consist of both quantitative and qualitative data: tree prevalence measurements to inform community resource assessments along with interview and observational data regarding community interest in and markets for neem. Data from neem processing interactions were also analyzed to identify emergent themes and points of interest around how the work progressed to date and how the process may be improved in the future.[10]

<table>
<tr><th colspan="7">Process Improvement Emergent Themes</th></tr>
<tr><td colspan="7">Participation</td></tr>
<tr><td colspan="2">Geography</td><td colspan="3">Gender</td><td colspan="2">Season</td></tr>
<tr><td colspan="7">Neem Processing Improvement</td></tr>
<tr><td>Season</td><td>Storage</td><td>Quality</td><td>Extraction</td><td>Technology</td><td>Communication</td><td>Training</td></tr>
<tr><td colspan="7">Neem Market</td></tr>
<tr><td colspan="2">Channel</td><td colspan="3">Price</td><td colspan="2">Byproduct</td></tr>
</table>

Information available on neem markets was limited, indicating only a small handful of salable products and buyers. Qualitative data were analyzed in the context of secondary literature references, for example on neem processing methods.

The data around neem tree prevalence were analyzed to present a complete view of the status of neem as a natural resource in each village, in addition to forming comparisons among the villages. For example, maximum, minimum, mean, median, and inter-quartile range were identified for DBH, height, and crown width both overall for Moléntah and in each village. The neem trees in each village were compared to population and inventoried land area estimates in order to identify potential underlying situational indicators impacting the neem resource base. Physical measurements were extrapolated based on secondary literature seed and oil yield references to estimate marketable quantities and potential income. These quantitative data are primarily intended to serve as a baseline dataset, for example to enable future measurement of tree growth, study of tree use over time, or analysis of local development of neem processing capacity.

[10] The focus on emergent themes (e.g. vs. word prevalence software analysis) reflects the constraints of the field (limited battery and electricity availability for tape recording or typing) and primarily the issue of multiple linguistic translations: research questions (French) via translator to Bissa; responses (Bissa and French) via translator to French); and all activities (French) via author to English. Thus handwritten notes from various interactions were coded by hand for emergent themes and interest areas.

## RESULTS & DISCUSSION

### Note on Timing of Research

Research is impacted by many constraints and competing objectives, such as participant and funder timelines (Lewis 2003). Frequently, repeated data collection may be necessary, for instance to follow through to the next cycle of action research, or to gather data during various seasonal or political cycles. This research was conducted as a pilot study not only because of its introductory nature, but also because of a timing constraint: the available research period coinciding with Burkina Faso's rainy season. For all aspects of the research, participation was impacted by the need for agricultural planting and cultivating in accordance with precipitation patterns, as well as limited mobility due to precipitation. Additionally, neem itself is in its secondary season during the rains, with far more seeds produced during the dry and hot months of January to April. But in some ways these constraints were promising for the project's success: if people were willing to participate with relatively little neem available even while farming and dodging rain showers, then they may be more likely to continue later when seeds and time are relatively abundant.

### Introducing Neem to Community Groups

Attendance at initial neem meetings ranged from ten to 25 adults per village, primarily women, although key men were present at each. Attendance at the meetings was affected by the fact that the research took place during cultivation season; thus some community members were busy in the fields. In addition, local politics and peer pressure impacted some individuals' decisions to participate, with some individuals encouraged to attend or discouraged from attending meetings by other community members (i.e. elders, religious leaders, husbands, and friends). The most successful meeting in terms of attendance was tacked on to a previously existing community group meeting as an additional item for discussion. However, buy-in was created across all four villages during the introductory meetings, and participants committed to share the information discussed with neighbors unable to attend.

| Introductory Community Meeting Emergent Themes |
|---|
| common curiosity about neem marked by limited experience |
| orientation toward utilizing natural resources in a socioeconomic context |
| desire to earn income |
| willingness to participate |

Interestingly, a few community resources surfaced that had already experimented with or been trained in neem processing. Participants stated that an older woman in Renyone had made soap from neem oil before (2009 06 15 focus group in Renyone). In Wasanti, two women had attended training in neem processing hosted by the local agricultural extension service, although they were no longer confident in the details and had not shared this information with neighbors at the time (2009 07 07 inventory in Wasanti). One woman in Renyone, and three from two different neighborhoods of Wasanti had collected neem seeds previously and still had them stored; one had included them in her compost for her fields (2009 06 22 inventory in Renyone), the others did not know what to do with the seeds but thought they might be useful (2009 07 10 inventory in Wasanti). One other family in Apalko had experimented with neem oil extraction independently, successfully extracting oil the way peanut oil is extracted there, by pressing with water after grinding roasted seeds (2009 06 27 inventory in Apalko). A local entrepreneur in a neighboring village not included in this research had hired people to gather neem seeds for him, which he had applied to his fields after learning of neem's insecticidal properties during his travels throughout the region (Pers. Comm. 2009 07 01). These perspectives added valuable insight into both external training opportunities and local expertise available to develop neem processing efforts and cottage industry such as soap-making. Unfortunately the current agricultural and forestry extension agents did not have neem processing curricula or guidelines readily available, and the older woman who had previously made soap did not participate in the pilot. Nonetheless they remain strong leads for future development of neem in Moléntah.

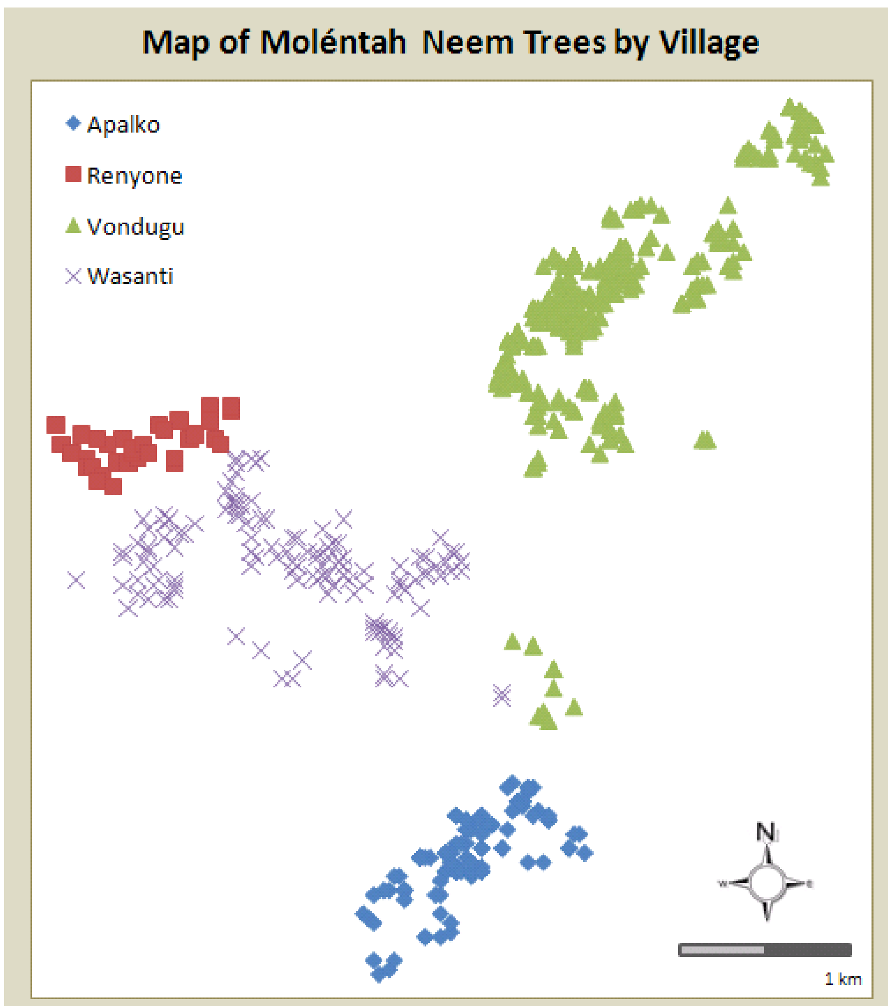

Near a family compound in Apalko, field assistants measure neem using locally available materials.

In moving forward with the proposed pilot activities around neem, each village identified two literate youth, one male and one female, to join me in inventorying existing neem near households and surrounding fields. The Wasanti male served as a lead field assistant, helping to translate at some introductory meetings in addition to remaining available for additional measurement support in Apalko and Vondugu. I added a second (male) lead field assistant to assist with translation at other introductory meetings and support tree measurement in certain neighborhoods of Wasanti as well as in Renyone and Vondugu. In Vondugu the two selected females did not participate in tree measurement beyond the first day despite repeated invitations, although they did remain involved in neem seed collection and the oil extraction pilot. Thus the Vondugu measurement team generally consisted of myself, the Vondugu male youth, and the two lead field assistants.[11]

## Resource Assessment: Neem Tree Inventory

### *Distribution of Neem Trees*

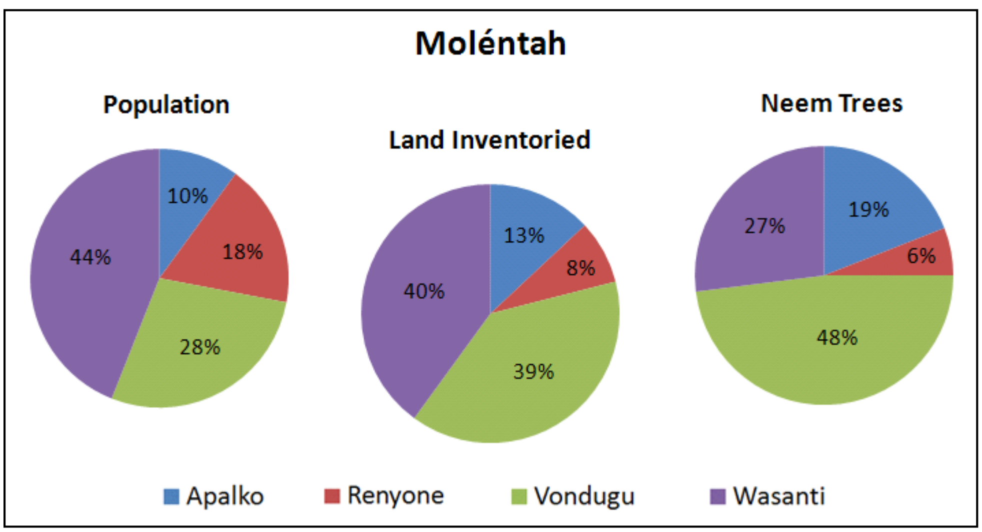
Altogether we identified and measured 744 neem trees on approximately 350 hectares of land near houses and surrounding fields in Moléntah. In the smaller villages of Apalko and Renyone, this resulted in 141 and 45 neem trees, respectively. 30% of Apalko's neem trees are in one relatively dense stand, frequently lopped or coppiced for wood poles. In the two larger villages of Wasanti and Vondugu, we identified 200 and 358 neem trees respectively.




[11] A village guest visiting from Ghana graciously helped us measure one day, but did not join us again due to the heat of the afternoon sun.

The varying incidence of neem in the different villages, relative to population and land area inventoried, is interesting. In particular, Vondugu demonstrates an abundance of neem trees relative to the other villages, boasting nearly half of the neem trees in Moléntah. And this impressive number despite comprising less than a third of Moléntah's population, and only 39% of the land inventoried in this study. Both Vondugu and Apalko account for more neem trees than either their populations or land area would suggest.

That is, on the surface, Apalko appears to have a relative abundance of neem, until we recall that nearly 1/3 of Apalko's neem trees are fairly densely grouped in a small area. Both Vondugu and Apalko contain instances of relatively thick neem tree groups, and as such provide some insight into single species stand characteristics (generally lower yielding than individually located neem trees), which could help to inform local plantation approaches in the future. So although in Apalko the relative abundance of neem trees is high, for example, the growth and seed production of a significant portion are limited by competition. Excluding this 'neem forest', Apalko exhibits a constant 10-13% proportion of Moléntah's population, land inventoried, and neem trees.[12]




[12] In the field, it appeared that Apalko was actually quite forested relative to its neighboring communities; however the trees tended to be shea as opposed to neem. Indeed Apalko is known for availability of shea nut butter when other nearby villages have run out (Pers. Comm.).

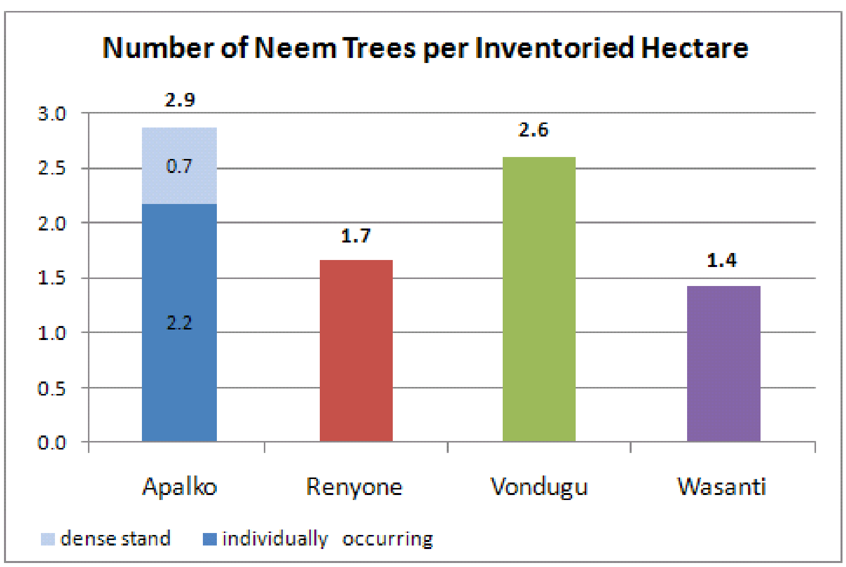
Renyone and Wasanti trend in the opposite direction, with a smaller proportion of Moléntah's neem trees than either population or land would suggest. Renyone exhibits a steady 6-8% of Moléntah's neem trees and land; however it appears to have a much higher population density, at least for the area inventoried in this study. These results suggest that Renyone may be a more centralized village than the others; thus the amount of land inventoried was reasonably productive in terms of neem, but limited in terms of geographic scope. The size of the population indicates that there may be a significant amount of outlying land which may house neem but was not inventoried, or which could potentially be planted with neem were the community to embrace neem as an economic undertaking.

Wasanti is lacking in neem relative to land or population, with its proportion of Moléntah neem trees approximately 35% lower than its proportion of population or land measured. While this may indicate a bias toward other types of trees, similar to the shea in Apalko, the relatively low proportion of neem could be a sign of deforestation. Indeed the local forestry extension agent is concerned with the relative deforestation in Wasanti compared to its neighbors (Pers. Comm.). Despite this concern, due to the relatively large land area that Wasanti encompasses, its absolute number of trees is significant if taken as a whole. That said, local history and politics would likely preclude the different neighborhoods of Wasanti from pooling together their neem, thus reducing the relative purchasing power of any Wasanti organization to roughly that of Apalko's neem resource base.

The proportion of Moléntah's resources attributable to each village is not the only indicator of relevance, particularly since collaboration across villages (or even neighborhoods) is not a given. To estimate the neem resource per village, neem trees per hectare and per person were calculated. Neem trees per person is perhaps more usefully considered as the number of community members per neem tree, in an effort to elucidate the extent that individuals or families would need to share the neem resource, were a village's neem trees equally accessible to each of its residents. For example, a Moléntah woman generally has 4-8 children and 1-2 elders living in the compound, so up to ten people sharing one neem tree could still correspond to one tree per family, or one tree per 1-2 neem processors, since women were the primary participants. As illustrated below[13], such a conceptualization suggests that Renyone would be particularly strained, with many more people competing for the same neem resource than in other villages.

[13] Background neem tree batik artwork by Belemtougri Senou, Centre National d'Artisanat d'Art, Ouagadougou.


The number of neem trees per inventoried hectare is another key indicator of the neem natural resource base, relevant for both environmental and socioeconomic considerations. The results range from 1.4 to 2.9 neem trees per hectare, a result appropriate to the Sahelian parkland agroforestry approach mentioned earlier, especially considering the presence of other native trees such as shea and néré. As with other neem indicators in Moléntah, Wasanti and Renyone trail behind Apalko and Vondugu. Apalko's dense stand of over forty neem trees favorably biases its



general neem tree abundance; correcting for this lowers Apalko's results from nearly three to just over two trees per inventoried hectare, leaving Vondugu in the lead. Of course any village's neem capacity could improve, were neem to be naturally present or become cultivated on further outlying lands than were included in this study – for example, *en brousse* where many community members' agricultural fields are located.

Overall, Vondugu shows the strongest current position in terms of neem trees as a natural resource base.

*Characteristics of Neem Trees*

Neem trees generally grow slowly in their first years, reaching maturity by year 10-15 with a lifespan of 150-200 years. Neem generally grows up to 2.5 m in circumference – approximately 0.8 m diameter at breast height, or DBH (NRC 1992, Norten 1996, Neem Foundation 2008). Noted for its genetic variability, neem exhibits great variation – tree by tree and location by location – in growth patterns and extracted compounds' relative strengths (Obara et al 2004, Kaura et al 1998, FAO/INN 2007). Thus estimates from the literature tend to be broad and should be verified locally whenever possible.

This research created a baseline inventory of Moléntah neem trees and associated growth measurements – including diameter at breast height, tree height, and crown width – along with observed characteristics – including location, ownership, age, and distinguishing features, for example wounds, pollarding, or split trunks. These are summarized here and discussed in turn below.

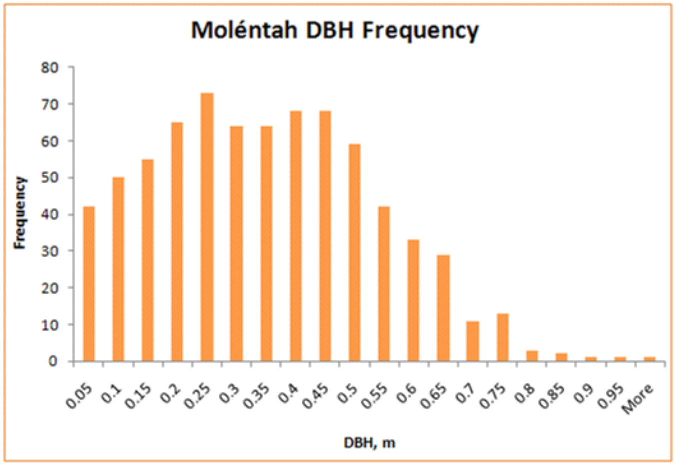
| | Circumference (m) | DBH (m) | Tree Height (m) | Crown Width (m) |
|---|---|---|---|---|
| **Maximum** | 3.02 | 0.96 | 18.6 | 19.6 |
| **Minimum** | 0.02 | 0.01 | 0.4 | 0.2 |
| **Mean** | 1.03 | 0.33 | 8.4 | 7.3 |
| **Median** | 1.01 | 0.32 | 8.5 | 7.1 |
| **IQR (mid 50% range)** | 0.57 – 1.44 | 0.18 – 0.46 | 6.3 – 10.5 | 4.6 – 9.6 |

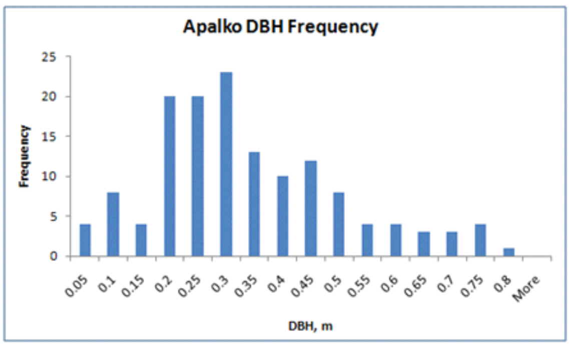
Four trees clearly stand out as the most robust specimens in all of Moléntah, with two of three measurements (DBH, crown, and height) ranking in the top 1%, and all measurements ranking in the top 3% of the entire inventory. A fifth tree also had all three measurements in the top 3%, but only crown in the top 1%. Beyond the four listed below, there were three other trees exceeding 0.8 m DBH and a total of 21 over 0.7 m DBH. Five trees kept pace with the leaders by also rising above 16 m in height, while the crowns of three trees not listed below also spread beyond 17 m in width.

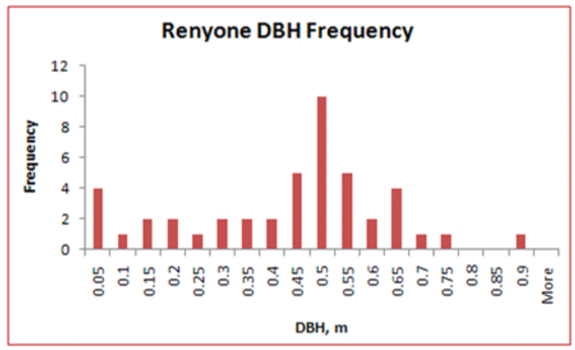
| **Moléntah's Largest Neem Trees** | | | |
|---|---|---|---|
| **Circumference (m)** | **DBH (m)** | **Height (m)** | **Crown Width (m)** |
| **3.02** | 0.96 | 16.96 | 18.13 |
| **2.45** | 0.78 | 18.57 | 19.56 |
| **2.67** | 0.85 | 16.04 | 17.73 |
| **2.21** | 0.70 | 16.50 | 17.14 |

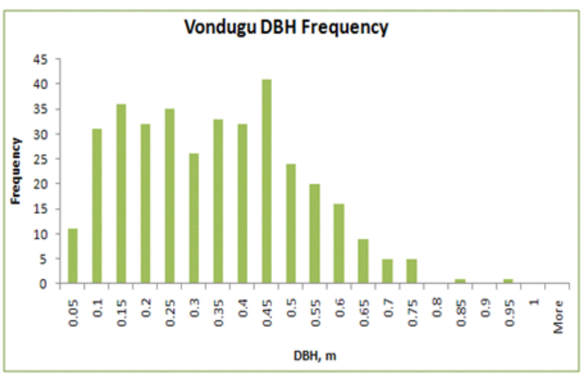
While each village had multiple contenders for Moléntah's largest neem – with some combination of two DBH, crown, or height measurements ranking in the top 3% – remarkably the four largest are all located in Wasanti, three in the same neighborhood and the fourth in the adjacent neighborhood. The fifth largest tree is located in Vondugu. It is unclear whether physical environment or social context is most responsible for these trees' success, but such answers could potentially serve as a model for facilitating conducive growth elsewhere.

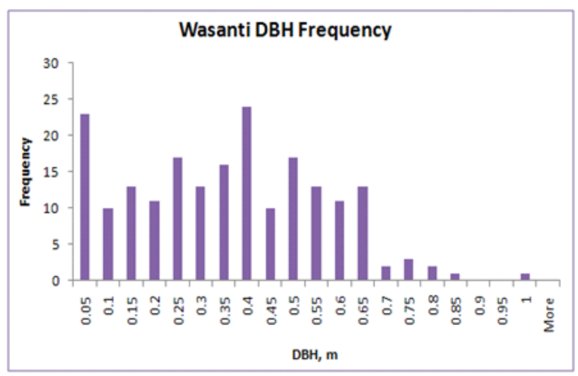
<u>Diameter at Breast Height</u>. In Moléntah, 41 neem trees reached 2+ meters in circumference, while only five of those exceeded the typical fully grown neem girth of 2.5 m. The largest measured 3.02 meters around, for a DBH just shy of one meter. Three quarters of Moléntah's neem trees have a DBH less than half a meter. The frequency distribution of Moléntah neem trees (see below) indicates fairly even growth, with an average DBH of 0.33 meters. The distribution is skewed, representing numerous small diameters and thus a significant number of young specimens.



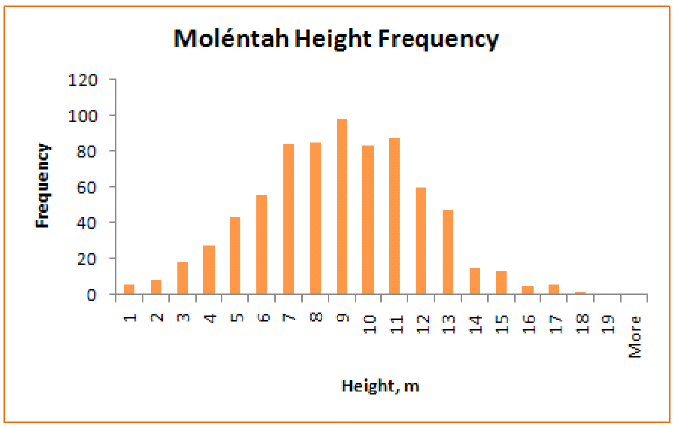



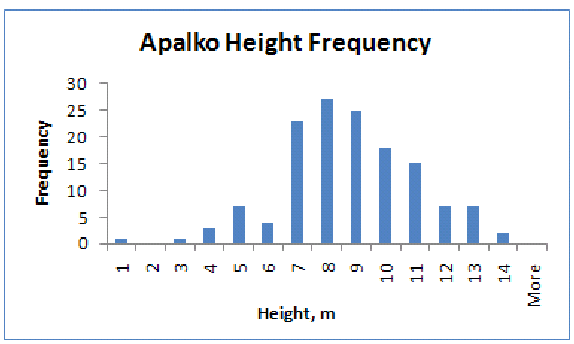



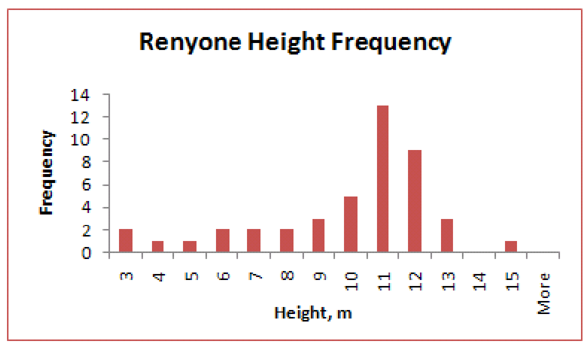



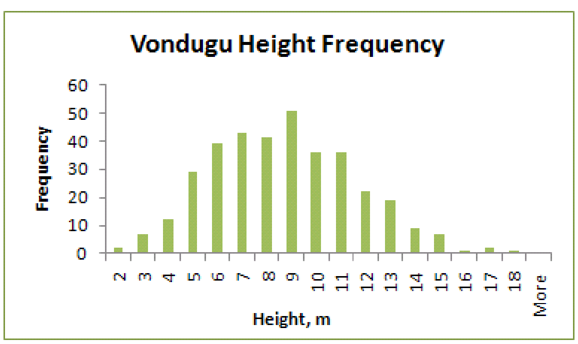

Comparison of diameter distributions among the four villages is not so uniform. Wasanti in particular appears to have many new seedlings. Apalko's diameters are not very large compared to the other villages, rarely exceeding half a meter. Renyone's neem trees are clustered around .45 to .65 m diameter, perhaps indicating a focused planting effort at some point in the past, with a recent small spike in saplings as well. It appears that Wasanti had an early adopter of neem trees operating for several years before planting was implemented rather abruptly and in a sustained fashion on a larger scale. Overall many of the neem in Moléntah exhibited thick as opposed to tall trunks; almost 10% of trunks split, in mature trees often just above breast height, enabling quite a broad canopy of shade.

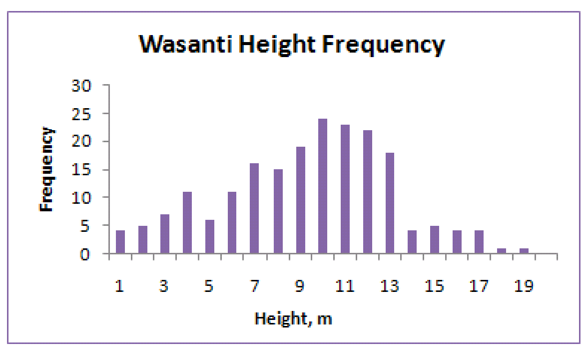
Height. As mentioned previously, height data were gathered for 65% of inventoried trees, the vast majority in Vondugu and Wasanti. A linear regression was fit to complete the data set, with most of the tree heights of Apalko and Renyone predicted from the regression. Regression results are included in Appendix B. Heights reach up to 18.6 meters, with only 27 trees exceeding 14 meters height, and only fourteen trees surpassing 15 meters tall. Half of all heights fall between 6.3 and 10.5 meters. It appears that Moléntah's neem trees are relatively short, with the literature identifying typical height of a mature neem tree as 12-30 meters. This may be due to age, environmental conditions, lopping, or genetics.



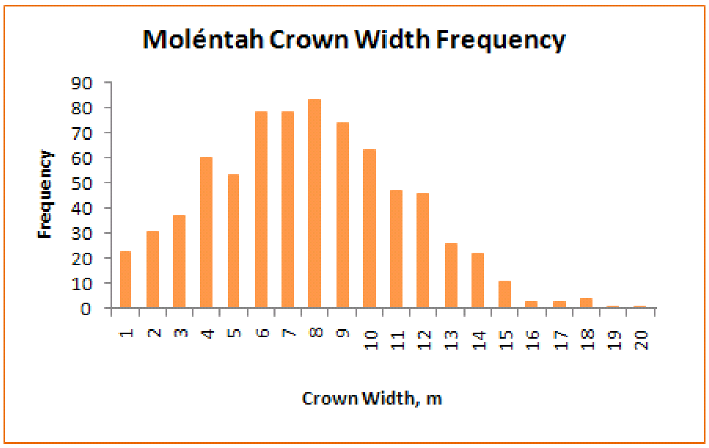

The frequency distributions of height reinforce previous findings, with most of Renyone's neem trees likely planted around the same time and on the earlier side of neem in the area (to reach 10-12 meters currently). Apalko exhibits a marked lack of short trees, indicating either a lack of

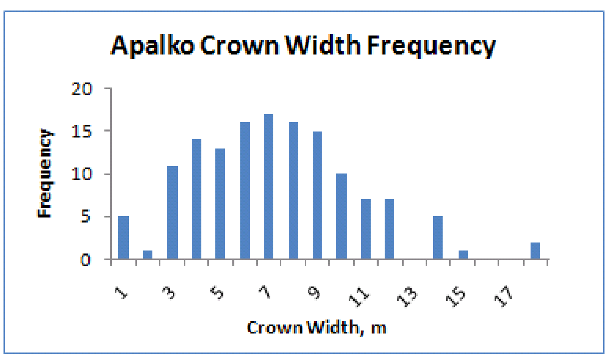
– or given DBH data, more likely relatively tall – saplings. The number of saplings indicated by Wasanti's DBH distribution does not fully match its height distribution, indicating a broader spread over the shorter heights than DBH would suggest. However, the patterns of its larger trees indicate consistent growth across DBH and height. Renyone's data continue to indicate a low but steady replanting pattern. Vondugu also shows many saplings that are taller than DBH might lead one to predict.

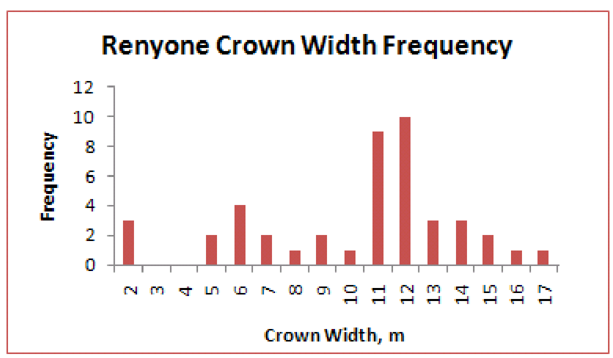
Crown Width and Lopping. In Moléntah, neem is traditionally most prized for the shade its canopy offers, welcome respite from the sun's intensity. However, community members indicated that they often remove neem saplings from agricultural fields to prevent that same shade from inhibiting crop growth, while those trees that mature are often pollarded or coppiced for wood and for facilitation of sunshine on the land (Pers. Comm.). Indeed signs of pollarding were manifest in over 8% of all inventoried trees, with Vondugu having significantly cut only 2.8% of its mature neem trees while each of the other villages significantly cut 4.4% of their mature neem trees. These fairly low proportions of recent, major lopping may indicate that mature neem's primary wood use for construction and fencing is limited enough to remain sustainable at the aggregate village level, with a twenty year cycle leaving enough time for trees to reach relatively far past maturity before lopping would become necessary again. Relatedly, the observed cutting proportions would not significantly impact seed production by neem trees at the aggregate level. The focused nature of the lopping data – a handful of major cuts instead of a branch or two removed from every neem tree encountered – also supports community observations that neem is not a preferred fuelwood (Pers. Comm. 2008).

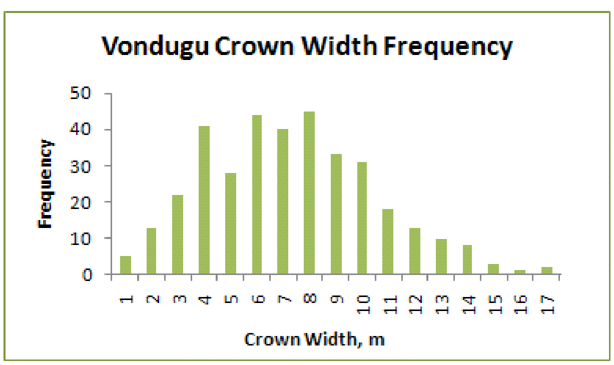
Neem trees lopped for lumber in Vondugu (L) and Wasanti (R)

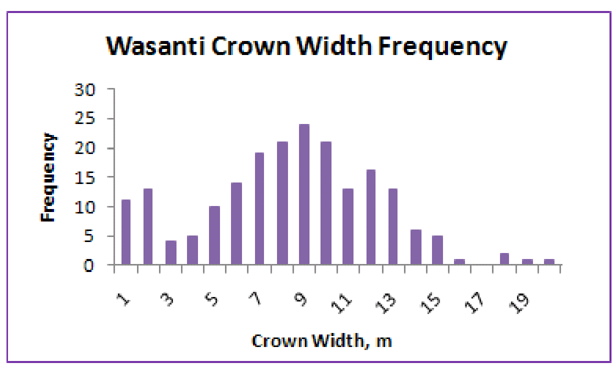
To gain a better understanding of the potential shade a neem tree might impose, and because the state of the crown gives insight into tree growth, crown width was measured for all inventoried trees, even when the tree had been recently cut. Crown measurements are exhibited below; they range from the DBH of lopped trees to an impressive 19.6 meters. Twenty-three neem tree crowns exceed 14 m, a dozen exceed 15 m, while only two surpass 18 m. The middle 50% ranges from 4.6 to 9.6 meters, with an average crown width just over seven meters. Rao (2001) states a typical crown spread of 10m; the data support the field impression that Moléntah neem crowns spread wide, with nearly a quarter of all trees surpassing the 10 m crown norm even as only half that many attained the lower bound of typical height, and three quarters of trees' DBH measured below half a meter. Most Moléntah neem trees occur individually and as such their crown growth would not be significantly limited by competition with neighboring trees, thus low crown widths likely reflect either young trees or pollarding practices.



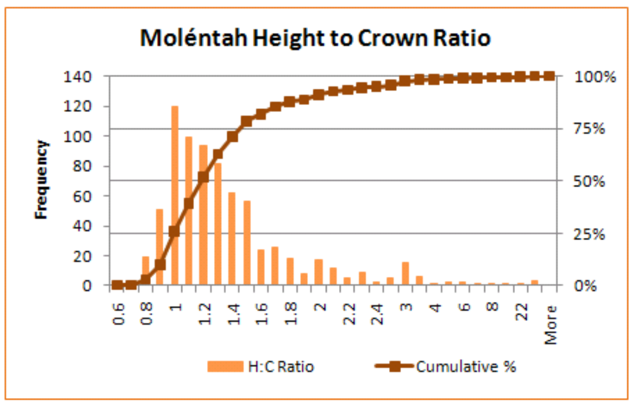



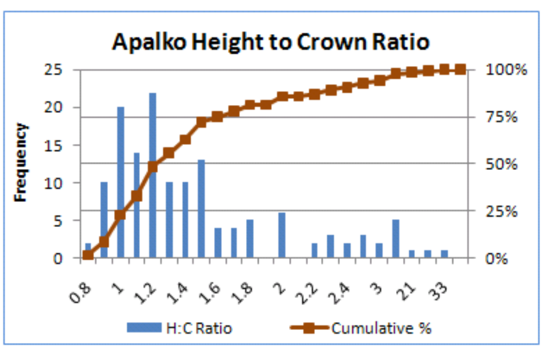



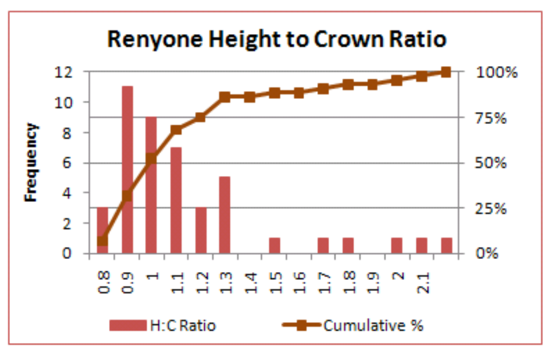



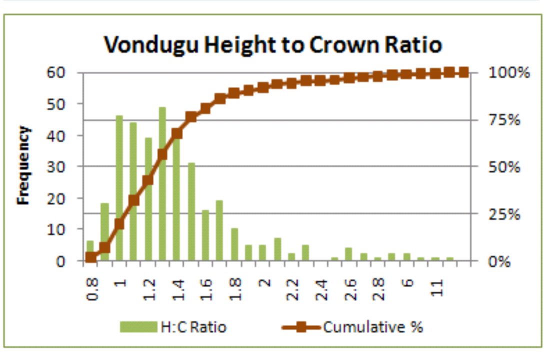
The village distributions are interesting, with Apalko in particular likely showing some severe lopping of a handful of trees. Both Vondugu and Renyone have a smoother and more continuous representation of large crown width than their DBH or height distributions suggest. Renyone's smaller crown widths indicate either some lopping or some saplings that likely resemble bushes rather than trees at this stage.

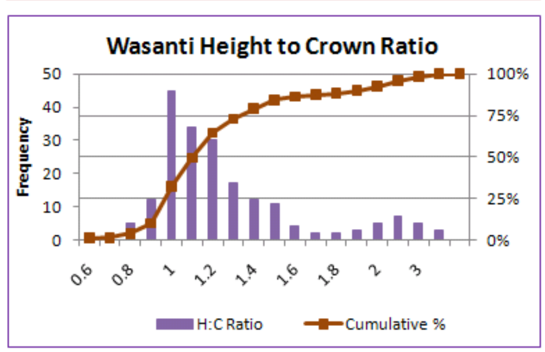
<u>Height:Crown Width Ratio</u>. A few trees measured the same height as width, but approximately three quarters of Moléntah neem trees were taller than their branches were wide, as indicated by where the cumulative percentage crosses the ratio of 1 in the diagrams below. This is likely in part due to the relatively young age of neem trees in the area, supported by the fact that only half of Renyone's typically large (and thus likely older) neem trees are taller than they are wide, suggesting initial height growth followed by crown emergence as neem matures.



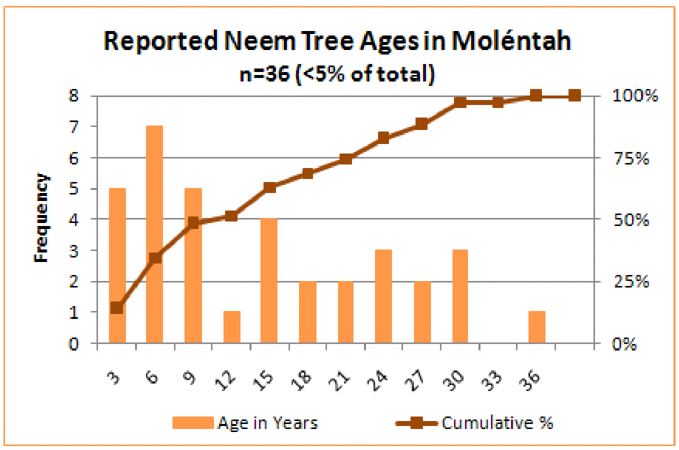



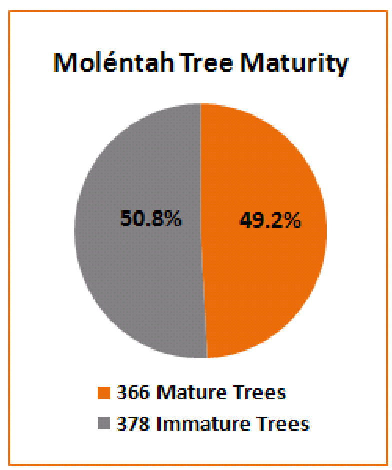



The results may also have to do with variations in tree genetics or spatial context, as well as any influences on sunlight, soil quality, and groundwater depth and availability. Wasanti in particular stands out as having a few quite 'wide' neem trees, which could be bush-like saplings or might also be very wide canopied but stocky trunked mature specimens. Vondugu neem appear to favor height over crown spread slightly more than the other villages and Moléntah as a whole. This could have to do with the relative abundance of trees in Vondugu, creating more competitive spacing that drives trees' vertical growth as opposed to enabling horizontal spread.

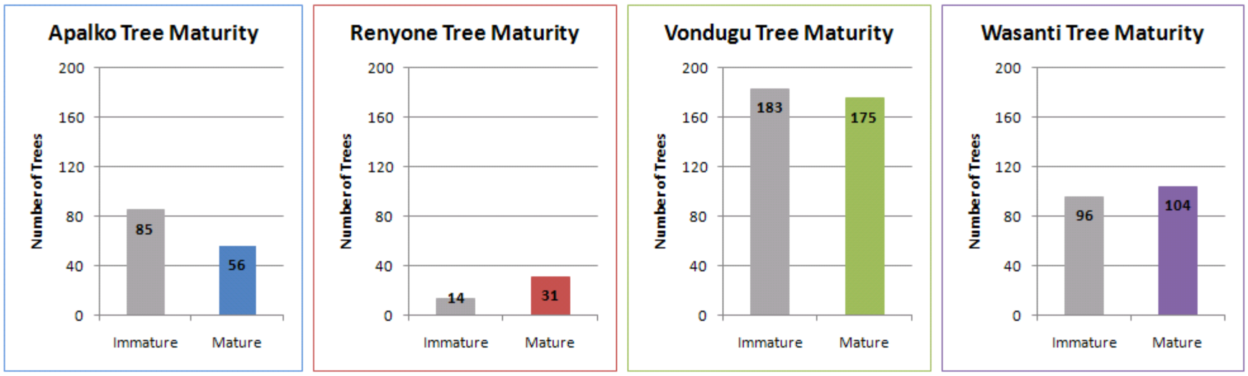
<u>Tree age and maturity</u>. Most community members did not know the age of their neem trees; however several owners were quite certain of tree age and planting circumstances. Age was confidently reported for 36 trees, suggesting that some neem are intentionally planted, for example to commemorate the birth of a child, or when a new compound is constructed (2009 06 12 inventory in Wasanti). Families were sometimes quite protective of newly planted neem trees, at least in part because they represent a household investment, with one owner quite distressed at her inability to protect two of her five neem saplings from severe damage by neighborhood children (2009 07 08 inventory in Wasanti). Inventoried neem trees were classified as immature or mature, according to DBH, growth and seeding patterns observed in Moléntah. For example, trees were assumed to have limited seed production if they exhibited small (<30 cm) DBH, due to young age or clustered habit, or if they were recently lopped; thus the tree would be classified as immature. This DBH boundary aligns with an approximate ten-year old tree, based on the limited age data available for Moléntah neem trees.




Only 49% of the inventoried neem trees in Moléntah could thus be classified as mature, which corresponds with age data and the relatively recent history of neem in the area. It also suggests significant potential growth in neem productive capability as half of the current neem tree population reaches maturity in the coming years. However, the state of neem varied by village, with Renyone



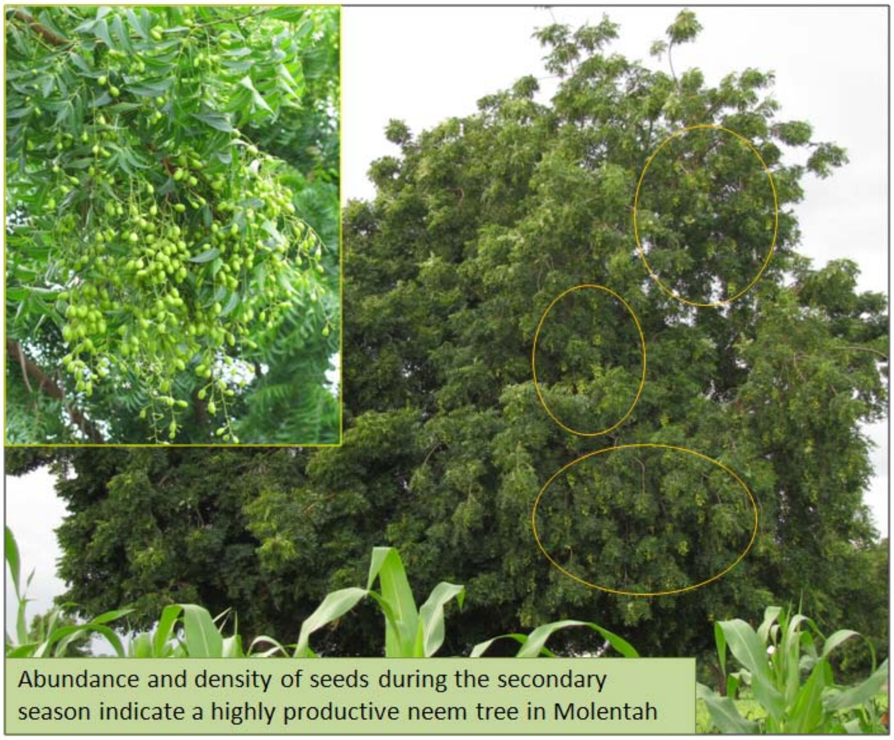
having twice as many mature as immature trees; Wasanti having slightly more mature than immature trees; Vondugu having slightly fewer mature trees than immature; and Apalko having 50% more immature trees than mature. This may indicate that neem planting occurred at different time periods in different places, or may indicate generally divergent use, maintenance, or reforestation strategies of the different villages.




*Productive Potential for Neem Seeds in Moléntah*

Neem can be expected to bear fruit as early as years 3-5, producing 20-50 kg of fruit per year from its 20th year onward (NRC 1992, Norten 1996, Neem Foundation 2008, Rao 2001). Each fruit generally contains one seed, although some contain two. Given the variability among neem trees, for estimation of Moléntah neem productive potential, conservative but general estimates from secondary literature are used, due to lack of primary data and limited geographically explicit and relevant secondary literature (NRC 1992, Norten 1996, Muñoz-Valenzuela et al 2007, Kundu & Tigerstedt 1997, Nanang et al 1997, Kaushik & Vir 2000, FAO/INN 2007, Pers. Obs.).

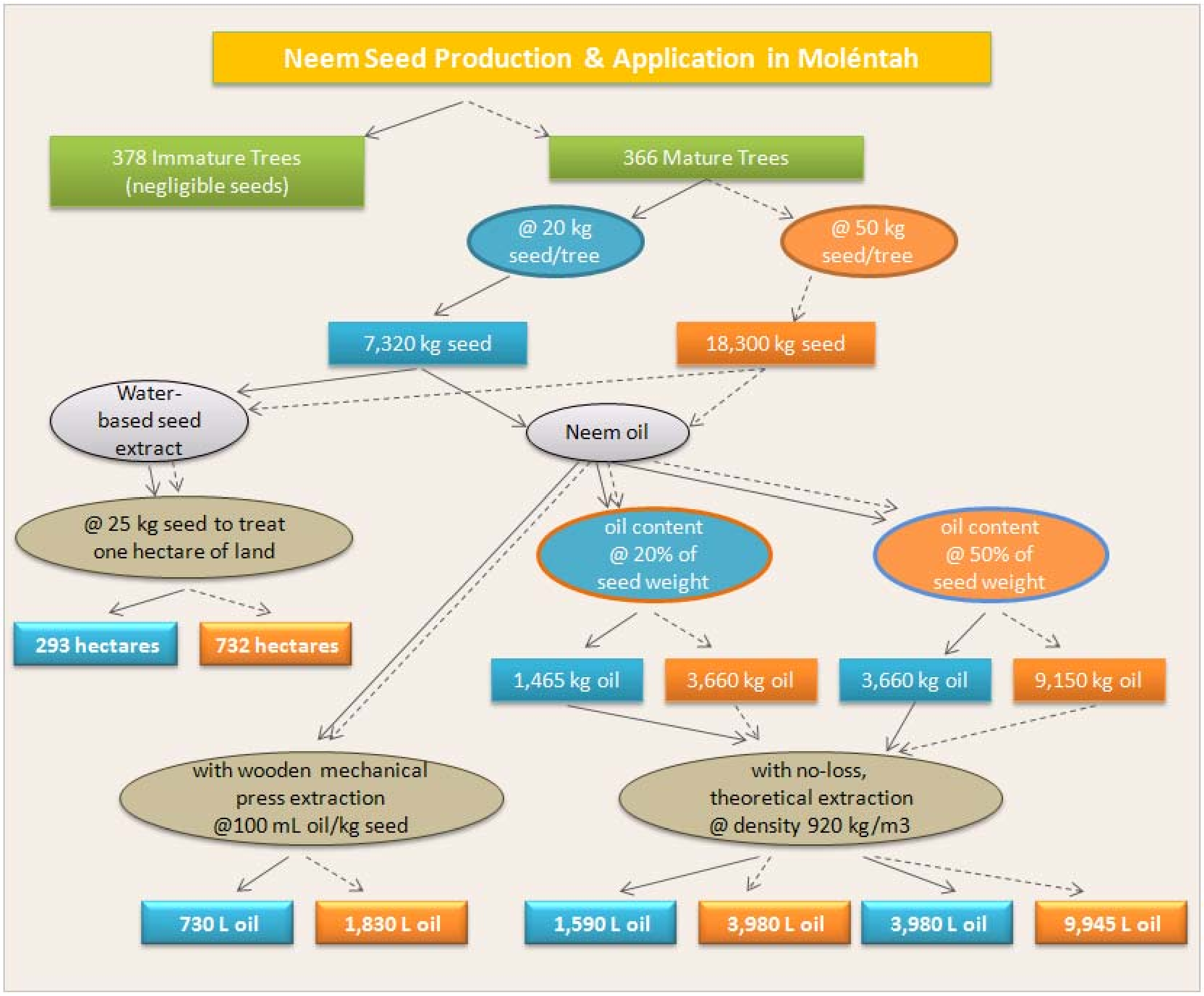
In order to estimate potential seed production and availability of Moléntah neem trees, I assumed negligible fruit production of trees classified as immature (DBH <30cm and/or evidence of significant lopping), although some seed production by 5-10 year old trees is expected and was observed in actuality. Assuming full productive capacity to be the lower limit of 20 kg seeds per mature tree per year, Moléntah neem could produce on the order of 7,320 kg (over seven tons) of seeds altogether, which could be directly distributed to fields or sold as seed cake (ground neem seed or more commonly, residue after oil extraction). The high estimate of seed production, corresponding to 50 kg seeds per mature tree per year, suggests an optimistic bound of 18,300 kg of seed production annually.



Abundance and density of seeds during the secondary season indicate a highly productive neem tree in Molentah

Often neem oil and compounds are extracted using water or solvents. To view neem productivity potential in these terms, first we approximate that 25 kg of neem seed can produce enough water-extracted neem oil solution to treat a one-hectare field (NRC 1992). Thus Moléntah could produce enough neem to treat at least 293 hectares – and up to 732 hectares – with a water-based suspended solution. That suggests significant availability of a neem biopesticide to Moléntah farmers, given that this study's focus on households and surrounding fields resulted in approximately 350 hectares of land inventoried.

If use or sale of neem oil is preferred over neem cake, we would need to estimate Moléntah's neem oil capacity based on its potential range of annual neem seed production – according to either the oil content relative to seed weight (a physical maximum), or the volume of oil that can be extracted from a given weight of seeds (a practical estimate). Sources indicate that neem seed oil content is equivalent to 20-50% of seed weight – we will start with 20% as a conservative estimate of oil content here (Norten 1996, Muñoz-Valenzuela et al 2007, NRC 1992, Venkateswara Rao et al 2008). Thus the lower bound of 7,320 kg of neem seed production would contain at least 1,465 kg of oil, while the upper seed production bound of 18,300 kg of seed would contain at least 3,660 kg of oil. Estimating neem oil density at 920 $kg/m^3$ (Venkateswara Rao et al 2008, Rao 2001, Pioneer Enterprise 2006, New Directions Aromatics 2009), it follows that Moléntah's mature trees would currently provide a minimum oil yield of between 1,590 and 3,980 liters of neem oil, were it all to be expressed from the available seeds. However, estimating neem seed oil content at its upper limit of 50% by weight, Moléntah could produce a maximum range of 3,980 to 9,945 liters (3,660 to 9,150 kg) of neem oil, depending on total weight of seeds produced annually. These calculations from physical oil content and neem density are upper estimates of potential yield of neem oil, assuming that all oil present can be extracted, with no accounting for loss.




Unfortunately the literature is scarce in estimating oil actually expressed from seed, once inefficiencies of press technology are considered. Rao (2001) states that one (metric) ton of processed neem seed gives 200 kg of neem oil – indicating a 20% ratio of seed weight to oil, which would correspond to the minimum physical estimates above of 1,590 to 3,980 liters. Norten (1996) suggests that using a wooden mechanical press, 1 kg of seed could produce approximately 100 milliliters of neem oil. This dramatically changes the anticipated yield of neem oil in Moléntah: pressing of Moléntah's 7,320 kg of neem seed could yield only 730 liters of neem oil – or if mature trees produced their maximum potential of 18,300 kg of seeds, then a maximum of 1,830 liters of oil could be expressed – and that with a mechanical press, not extraction by hand.

As indicated above, morphological and practical studies of neem tree, seed, and oil content and yields are limited in the literature. Muñoz-Valenzuela et al (2007) emphasize from research on a Mexican neem plantation that seed morphology and seed oil content are not consistently correlated, that tree age has no significant effect on oil yield, and that oil content varies, perhaps by tree provenance. Thus estimations of oil potential from neem tree measurements are challenging and are most appropriately based off of local sampling. The research in Moléntah originally aimed to track at least some individual trees' seed production in terms of weight and oil extraction. However, as discussed in the next sections, the season (cultivating for participants, and biologically secondary for neem seed production) along with the difficulty of extraction by hand limited this initial attempt to gather primary productive data.

**Seed Collection**

The process of seed collection was introduced during the group interviews, outlining key steps:

1. gather seeds that have already fallen to the ground;
2. keep seeds from different trees separate if possible for tracking purposes;
3. rinse the fruit pulp off;
4. dry in the shade to maintain chemical integrity and avoid mold/fungus.

Community members were then free to collect seeds or not, as their preferences and availability allowed. The opportunity and methods for collecting seeds were also repeated during the neem baseline inventory, were residents available to talk when we arrived to measure neem trees at their homes or in their fields. Mold/fungus and associated aflatoxins are a common concern with neem, particularly when the fruit pulp is not removed; thus instructions for Moléntah's pilot included rinsing the fruit's flesh off of the seed and leaving the rinsed shell to dry completely before storage. Emphasis was placed on drying rinsed seeds in the shade to preserve potency of the seeds' insecticidal compounds, however some sources do not identify any loss of insecticidal quality with seed exposure to sun during drying (Dreyer 1984, NRC 1992, Norten 1996). The shell would later be cracked off of and winnowed from the seed kernel, which would be milled into a powder for oil extraction. The collected seeds would be weighed before milling in an effort to track individual people's contribution to the final group oil extraction; in addition the amount of seeds produced by a given tree could be tracked in this way. Although it was both neem's secondary season and fairly certain that people would only collect a fraction of the available seeds from any given tree, the intention was to extrapolate Moléntah neem collection potential (biological production of and social capability to gather seeds) from these primary data, based on tree size and participation levels.

Weighing Neem Seeds in Renyone

Although men had been present and participated in the introductory group interviews, only women and children participated in seed collection. In fact, a high proportion of participating women were elders; with stated reasons being that the older women had time to gather the seeds during cultivating season due to their limited participation in cultivating, and that they had a relatively pronounced need for income generation given the social structure in Moléntah. In addition, older women tend to maintain knowledge of local natural resource use that younger generations are becoming less familiar with (Pers. Obs.); neem is a natural fit from that perspective.

Overall, participation was limited to a handful of people from each village, due in part to the rainy/cultivating season. In addition, neem processing was a pilot activity in Moléntah, with only 'early adopters' most likely to jump right in, taking on the risk of time away from food production to test an unknown domain for future, not current, income generation. While the quantity of data was thus of too small a scale to extrapolate neem collection potential from primary data, each village demonstrated interest, establishing a succinct core of pilot participants well poised to serve as resource people for further neem collection or processing efforts in each village. Thus women from three of the four villages did collect and dry seeds, resulting in nearly 20 kg of neem flour (ground decorticated kernels) for use in the pilot oil extraction, attended by representatives from each Moléntah village.

Four issues emerge: quality of the seeds collected; tracking seeds' tree source; abandonment; and temporal variation in seed emergence and ripening. Despite common instructions, people's collection practices varied. I several times came across neem seeds drying in the sun, as this is the common practice for drying everything in Burkina Faso. In addition, some of the seeds gathered exhibited mold and were partially discarded to protect the quality of any extracted oil or cake that might be used in the fields. The rainy season itself brings high humidity and sporadic rain showers which impede drying. Also, instructions did not emphasize storing the rinsed and dried seeds in a breathable container such as a rice bag; as such some seeds were stored in buckets, dishes, or plastic bags that would facilitate moisture collection and mold growth. Containers were also an issue in separating seeds from different trees – twice there were not enough containers available, and other times the practice was simply not followed, perhaps its intent unclear or unvalued given the secondary season. Most of the collectors did track the tree source of their seeds, however, laying the groundwork for future seed yield studies, although the data are insignificant at this time.

| Village | Participant | Seed Wt. (kg, with shell) | Kernel Wt. (kg, no shell) | Quality/Comments |
|---|---|---|---|---|
| Wasanti-1 | G.D. | 2.475 | 1.125 | OK; from home village, mixed trees |
| Wasanti-2 | B.S. | (0.95) | .505 | OK |
| Wasanti-2 | G.H. | 1.65 | (0.875) | Semi dry, dry fruit pulp remaining |
| Wasanti-2 | G.H. | 2.525 | (1.34) | Dry fruit pulp remaining, 2 trees mixed |
| Wasanti-3 | Z.A. | (0.28) | 0.15 | OK, 3 trees mixed |
| Apalko | B.A.M. | (0.9) | 0.475 | OK |
| Apalko | B.A.M. | (0.52) | 0.275 | OK |
| Apalko | B.A.M. | (2.36) | 1.25 | OK, same tree as next |
| Apalko | D.S. | (1.23) | 0.65 | OK, same tree as previous |
| Apalko | D.F. | 0.4 | (0.21) | Mold, some without shell |
| Apalko | S.B. | (0.33) | 0.175 | OK |
| Apalko | S.M. | 0.45 | (0.24) | Good |
| Apalko | B.A.S. | 0.35 | (0.19) | OK |
| Apalko | B.A.S. | (2.17) | 1.15 | Mold |
| Renyone | S.B. | (6.51) | 3.45 | OK |
| Renyone | S.B. | 3.6 | 2.15 | OK |
| Renyone | G.F. | (1.65) | 0.875 | OK |
| Renyone | G.F. | (4.25) | 2.25 | OK |
| Renyone | G.D. | 0.175 | 0.115 | OK |
| Renyone | S.A. | (2.08) | 1.1 | OK |
| Renyone | D.A. | 1.225 | 0.505 | OK |
| Renyone | B.M. | (0.85) | 0.45 | OK |
| **TOTAL** | **16** | **36.9 kg** | **19.5 kg** | |

Parentheses indicate estimated weight calculated from shell:seed weight ratio, based on data where each was available. Village numbers (e.g. Wasanti-1) refer to neighborhood designations.

One household exhibited an interesting dynamic somewhat typical of village efforts. A child had spent a significant amount of time gathering seeds in the hope of eventually using the seeds to help make her way through school. Her brother was one of the field assistants for the tree inventory in that village, and the entire compound was, in general, quite supportive of the initiative. However, when we arrived to weigh the seeds, family members informed us that her mother had thrown away the seeds a week or two prior. The mother spoke French and regularly conversed with me at the market, making me particularly surprised that she had decided to throw away the seeds. When asked why, she stated that she had simply thought the seeds had been present for too long; she had been cleaning out the house, and hadn't thought to ask her daughter, one of the field assistants, or myself whether or when the seeds might be utilized. This abandonment was an unfortunate demonstration of lack of communication – no inquiry from her and unclear process from us – and a general lack of willingness to engage despite understanding (2009 07 24 weighing in Apalko).

Another issue involved several women who collected seeds but did not follow through to participate personally in seed weighing or the oil extraction demonstration. This points toward a potential stratification of socioeconomic activity around neem, where some may view it worth their time simply to collect, but not to process or sell the neem, leaving that instead to others. Insufficient communication of the research process by myself, field assistants, or village leaders likely also played a role in these women's decisions not to stay personally involved after having collected seeds.

Temporal variation in neem seed emergence surfaced as a fourth issue, both village to village and even within villages. For example, neem trees in Vondugu tended to produce seeds several weeks later than the other villages, despite close proximity. Combined with later scheduling of the introductory meeting and neem inventory there, Vondugu participants did not actively participate in gathering seeds during the timeframe of this research – although representatives did attend the pilot demonstration – despite the relative abundance of trees there.

Thus seed collection took place at a pilot level, with adequate participation to represent each village. Enough seed was gathered to hold a pilot oil extraction demonstration, despite the small scale and mild concerns around seed quality.

**Oil Extraction**

Once the gathered neem seeds were weighed and decorticated, they were mixed together and fed through the Moléntah mill to produce neem powder or meal, from which neem oil could be extracted. Due to the limited amount of neem collected, a single demonstration was planned in order to have enough raw material to work with easily. All seed gatherers, field assistants, and two representatives from Vondugu were invited to participate in the pilot oil extraction. The extraction methods chosen were based on the literature's best practices (Dreyer 1984, NRC 1992, Norten 1996), which recommended steeping in water for the oil to rise to the top, or mixing with a bit of water in order to press out the oil by hand.

The process was delayed for a full week and even into the late afternoon the day of, due to hectic farming requirements and sporadic rainfall. Sixteen women, two men, and accompanying children came to the pilot demonstration. Not all of the seed gatherers attended; likewise there were a few attendees who had not gathered seeds.

Initially, a portion of the neem powder was combined with approximately equal part water, mixed slightly, and set to steep on the side for oil to rise. That method was not successful over three hours. The second attempt involved mixing a little bit of water into neem flour to create a dough, which was kneaded by hand to coax out oil. This method mirrors traditional oil separation in Burkina, for example peanut oil, although the neem seeds were not roasted, as heat deteriorates the efficacy of compounds within (Norten 1996). The seed flour contained visible oil, but extracting it by hand with water proved extremely difficult, at least given the moisture content of the seeds we worked with. After significant effort by two women, neem oil was successfully extracted from a small amount of neem flour. Given the late hour, the difficulty, and the threat of continued rain, the rest of the powder was divided up amongst participants in accordance with seed amount collected. Nonetheless a pilot, small-scale extraction of neem oil was accomplished, intended to demystify the process and prepare interested community members for the primary season.

Neem oil cold-pressed extraction pilot demonstration

Participation in the pilot oil extraction demonstration was impacted by the need for agricultural activity in accordance with precipitation patterns, and by precipitation itself, but involved multiple participants from each of the four villages and numerous verbal commitments to work with neem during its coming primary season (the dry months of January through April). With the remaining neem powder, some participants indicated they would try extraction again at home, some planned to again try the first method of steeping, and some planned to give the powder to a bean farmer to observe any effects on his field.

The pilot oil demonstration was primarily impacted by scarcity of time and limited success of extraction attempts. With additional time, the seed powder could have been dried more or roasted, and the extraction methods could have been modified one step at a time in an attempt to identify why the oil remained largely bound within the powder. In addition, the literature could have been reviewed again for well-explained extraction processes appropriate to a rural, low input context. Some sources recommend drying neem kernels for 3-6 months before attempting oil extraction, which was not possible in the timeframe of this research. Similarly, the rainy season's humidity and precipitation may have augmented the moisture content of seeds whose 3-6 week drying periods would have sufficed during the primary, dry season. Sun drying or roasting could have been performed on subsets of seeds or powder as well, even comparing efficacy with shade-dried raw seed powder and oil, had time and quantity been of less concern.

Participants remained primarily affected by the apparent difficulty of hand-extracting the oil from the seeds, as compared to the ease of gathering the seeds. The oil irritated the hand of one woman kneading the neem paste at length, and we all smelled like neem bitters for a time.

The most direct way of improving the neem oil extraction experience would be to find other Burkinabé community groups already processing neem that could serve as trainers in clear and effective local neem oil processing. The forestry extension officer articulated availability to inquire after potential groups, but none were identified as of yet. Information that I was able to obtain from contacts in the capital indicated that the largest neem processing community group had ceased activity about two years ago for reasons unrelated to neem (Pers. Comm.).

An enticing option is to seek mechanical assistance in expressing neem oil. Although locally available resources help to ensure sustainability in community development projects, so does appropriate technology. Thus a top priority for subsequent processing is to obtain or manufacture (preferably in-country) a simple and sturdy mechanical press in order to efficiently extract the oil from the seed kernel. Without the press, I anticipate that community members will likely shy away from the uncertainties and sheer hard work of extracting this new oil, instead sticking to the oils they already know, and perhaps simply using pounded neem as another input into compost pits – aiding the harvest, but not necessarily disposable income.

## Market Identification

The original goal of the research was to assess the income generating potential of processing neem byproducts (or utilizing them in agriculture). Identifying market outlets for any neem oil produced, as well as the price one liter of neem oil would command, was imperative in order to assess the value of time spent gathering seeds and extracting oil.

The first discovery was made during the Vondugu group interview, where two different men had experience with those buying dried neem seeds in the greater region. These secondary city merchants paid approximately 350 FCFA[14] per *plat* or approximately 70 FCFA per kg of dried seed, with or without fruit pulp (2009 07 04 focus group in Vondugu). However, there was no storefront or contact name to verify this regional opportunity, and a lack of regional transportation and lodging infrastructure dampens the convenience of the regional market.

I also inquired locally and in the capital, Ouagadougou, to discover contacts for other groups interested in or already processing neem, as well as potential oil press suppliers and neem oil buyers in order to establish market connections should the community members decide to pursue neem production later.

My contacts in Ouagadougou identified one primary dealer for neem oil, who paid between 2000 and 2500 FCFA per liter, approximately half the price that one woman from a different Bissa area claimed to have received previously in the capital. Nonetheless, the dealer's price is 2.5 times higher than the selling price of peanut oil, which is the most expensive oil for sale in Moléntah, representing a potentially lucrative business were extraction to be efficient in terms of effort and time. The neem oil dealer was out of the office each time I was in Ouagadougou, and did not return my contact's calls until the fall, having misunderstood that we wanted to sell neem oil immediately but having been saturated himself at that time. Such market saturation suggests that additional neem outlets and even international distribution partnerships or basic market demand may need to be established in order to have a purchaser for any neem oil produced by Moléntah. Along these lines, neem processing may be more entrepreneurial than originally envisaged.

A third potential buyer for neem byproducts includes agricultural development projects currently operating in Bissa areas, particularly near the Bagré reservoir and focused on increasing rice production for food security in the country. While some such projects themselves purchase neem or require neem inputs in-kind from participants (Pers. Comm.), they may simultaneously stimulate local knowledge of and demand for neem agricultural inputs by those who observe the projects' successful use of neem. Thus local market development is not out of the question.

[14] An exchange rate of 450 FCFA to $1 is used here.

With these market opportunities and constraints, the aforementioned productive capacity of Moléntah neem enables monetary estimates to be made from regional and national market prices. In terms of kg of seed, a mid-range scenario of seed production indicates that Moléntah could see annual income of nearly 900,000 FCFA, or approximately $2,000, were all neem seed to be sold in raw form to regional dealers. Were the seeds to be processed locally into oil, assuming a low estimate due to difficulties with extraction by hand, or even with a mechanical press, then 730 liters of oil could amount to 1,642,500 FCFA, or approximately $3,650, in annual revenues sold to the Ouagadougou market.

These conservative but reasonable estimates of the resource base and processing capability, combined with these market opportunities, suggest an amount of total income generation that corresponds to a community improvement project budget, such as school roof construction or a fruit tree afforestation effort. From a different perspective, a typical Moléntah woman might be pleased to earn 1000 FCFA per market day, for approximate annual earned income of FCFA 121,000. Thus in terms of bolstering the local economy, neem processing could add income equivalent to seven to thirteen women's annual market activities. In Moléntah, community earned income cooperatives are formed for far less return.

| Neem Market and Earnings Potential for Moléntah | | | | | | |
|---|---|---|---|---|---|---|
| | | | | Income from various Seed/Oil Production Capability Estimates* | | |
| **Market** | Buying Price | | | Low | Mid | High |
| **Regional Dealers in Raw Seed** | FCFA 350/*plat* (~70/kg) | Total | FCFA | 512,400 | **896,700** | 1,281,000 |
| | | | $ | 1,139 | 1,992 | 2,847 |
| | | Per Capita | FCFA | 100 | **180** | 255 |
| | | | $ | 0.22 | 0.40 | 0.57 |
| **Ouagadougou Dealer in Oil** | FCFA 2,250/L | Total | FCFA | **1,642,500** | 4,117,500 | 8,955,000 |
| | | | $ | 3,650 | 9,150 | 19,900 |
| | | Per Capita | FCFA | **330** | 825 | 1,790 |
| | | | $ | 0.73 | 1.83 | 3.98 |
| **Local Agriculture Project** | Unspecified | | | | | |

* Seed Capability Estimates: 7,320 kg; 12,810 kg; 18,300 kg. Oil Capability Estimates: 730 L; 1,830 L; 3,980 L. (See seed and oil production flow chart above.)

Without pooling potential neem proceeds for communal benefit, processing all available neem would likely translate into a mere 180-330 FCFA per capita per year – or one good lunch per person. While lunch is often a luxury in Burkina Faso, such per capita returns are not overly enticing even as supplemental income, and particularly given the amount of work required. However, likely only a portion of Moléntah residents would participate in neem processing, meaning that the proceeds would be split among fewer people. For example, given the typical family composition described previously, if primarily women sell neem, earnings per participant would increase five to ten times the per capita estimates. If only some women participate, earnings rise further. In addition, the opportunity cost of processing neem is reduced during its primary, dry season, during which few alternatives exist for income generation, and demands on time are reduced relative to the rainy farming season. In considering these pragmatic scenarios, neem processing begins to appear more attractive.

At the same time, it is likely that not all neem would be processed, thus reducing overall income generated. Balancing this concern, however, is the potential for the neem resource to trend toward or even surpass the high scenarios outlined here, given conservative approximations, exclusion of both the secondary season and any developing trees' partial fruit yields, future yield from currently immature trees (doubling the yield potential in less than ten years), as well as the potential to increase the number of neem saplings left to grow – in fields, *en brousse* beyond the inventoried, close-lying areas of this research, or even as plantations. Indeed during the inventory, several young men that we encountered heading to and from outlying fields exclaimed that they were no longer cutting down neem saplings since becoming aware of their potential value (Pers. Comm. 2009 07 06 and 2009 07 21).

Thus local Moléntah sale of neem seeds, cake or oil could potentially generate significant community income. Nonetheless local agricultural applications may be most practical at present due to extraction and market constraints. Depending on neem's impact on agricultural yield, the value of local use in the fields could potentially surpass income generation through neem sales.

## Implications for Future Neem Activity in Moléntah

From the above discussion of the neem resource base, piloted processing activities, and market identification, several themes emerge to shape future neem activity in Moléntah.

### *Season*

Clearly, the major neem seed gathering and storage process should take place during neem's primary season from January to April, in order to maximize the natural resource and labor availability, minimize competition with agricultural duties, and avoid humidity and other practical constraints of rainfall. As mentioned, neem's primary season conveniently falls during the dry season, when there is relatively little work to do. The primary impediments to active seed collection during neem's primary season are heat, hunger, and desire for leisure in anticipation of cultivation.

*Enhanced Participation*

In future neem-related activities, enhanced participation would be desired. Those who were involved in this pilot research are well positioned to facilitate neem processes in their respective villages or neighborhoods, and enough mature neem trees exist in each village to warrant the effort. Vondugu may require more active encouragement to undertake neem activities, given the limited participation in the pilot by this village. Participation may become organized according to time availability or monetary needs; thus older women or school-aged children may wish to organize themselves around neem processing for cooperative agricultural inputs or school fees. In addition, the role of men vis-à-vis neem has yet to emerge in complement or as threat to that of women. Over time, roles may take many forms as market opportunities necessitate travel, since oil presses require operation and maintenance, or if neem becomes successful business.

*Quality Assurance*

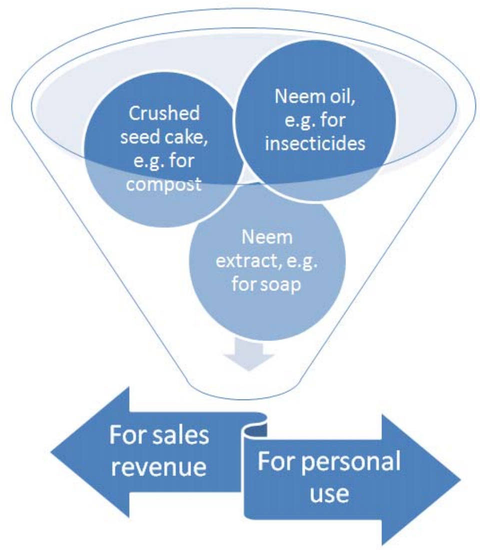
Local neem processing remains to be fully defined, tested, and documented. Seed drying and storage must seek to ensure quality while remaining efficient, for example through sun exposure or porous storage containers. Similarly oil extraction needs to be researched and/or tested to ensure quality and efficiency regarding drying and roasting seeds, or using presses, water or other solvents to separate the neem oil. The literature is conflicting and vague in its descriptions and recommendations, particularly relating to quality maintenance of chemical compounds in neem. Since laboratory testing is not available, experimental agricultural application may be the most appropriate method of verifying best practices, aside from identifying an experienced trainer in local harvest and extraction methods.

*Ease of Extraction: the Mechanical Press*

While the dry, primary season does not offer any major impediments to gathering neem seeds, the difficulty experienced extracting oil from the seeds will likely limit further processing efforts. It is possible that a longer waiting period after seed collection would facilitate oil extraction by enabling the seeds to dry more fully. Some sources suggest storing depulped seeds three to twelve months before extracting oil, in order to allow for sufficient drying and to process seeds when azadirachtin content is highest (Rao 2001, Norten 1996). Happily, this time period would enable oil extraction to take place just after the agricultural harvest ends but before the next primary season's seeds are ready for collection in Moléntah. However, in this case oil and cake would need to be stored for a few months before agricultural application, and some sources indicate instability and diminishing potency of neem oil and products (NRC 1992).

Waiting periods aside, for ease of oil extraction, the benefits of a mechanical oil press cannot be overemphasized. A hand-powered press is desirable to alleviate the need for power inputs; ideally the press could be manufactured locally, for example from oil drums, or at least purchased regionally. This would help to ensure sustainability of the technology by building mechanical skills and repair capability into the local user base, potentially also contributing to the local economy. And with a press, the challenge of efficient time and effort in neem oil extraction could be addressed to increase the feasibility of seed transformation into oil, and thus natural resource transformation into disposable income for a variety of expense needs.

*Multiple Byproducts and Channels*




Future neem activities could take many forms, as outlined at right. One fundamental question is whether neem is more beneficial for personal use in the home or on the fields, or for sale as a generator of disposable income. The answer to this question depends on the difficulties faced in the participant's life; for example if traditional medicines are needed for skin care, lice, or malaria, or if insect pests are plaguing sensitive crops, then personal use of neem may be as preferable as processing it for sale. But if money is needed to pay for school fees, health system services, business inputs, or other goods and services, then neem may be most attractive as a generator of income which can then be directed where needed.

Similarly, neem may take many forms in terms of byproduct. The simplest byproduct is crushed seed, which can be sold or mixed into compost. However, if extraction processes can be streamlined and simplified, then oil may be a more attractive, versatile production choice. Likewise, other neem byproducts such as leaf and bark tea may be preferred as inputs into cottage industries such as soap-making. Neem could process into any of these forms and fulfill personal or external market demand.

*Market Potential*

Development of the market for neem could shift both demand and supply dynamics, creating new incentives that need to be monitored to ensure sustainable natural resource use and social systems (Obara et al 2004, Elias 2007). The role of gender in developing neem was mentioned above; in addition the natural resource base of neem and any involved ecosystem processes should be maintained if not regenerated as neem's market potential is established. The goal is to persist – thus neem's market must be guided to flourish within the realities of the integrated agroecological and social systems already supporting Moléntah livelihoods and society.

## CONCLUSION

This research sought to bridge the gap between neem's potential uses for improvement of quality of life, and the requirement for basic needs provision and income in one of the most impoverished settings in the world. Through a neem inventory, pilot seed collection followed by oil extraction, and identification of potential markets, the goal was to transfer capacity to the Moléntah community to utilize neem both in daily life and for potential income generation.

Working with the community, a baseline measure of the local neem resource was completed, informing local knowledge of the resource base, promoting practical use of school-based learning through engagement of literate youth as field assistants, and serving the broader scientific community as one of relatively few such inventories conducted on neem. Pilot processing of neem transferred technical and project management skills to Moléntah community members and enabled identification of key factors influencing the feasibility of neem development, particularly applicable to Moléntah but potentially applicable to other rural, developing contexts. These outcomes were complemented by a local market analysis of neem, both to assess potential buyers and supply pathways as well as to estimate the socioeconomic value of neem byproducts. Altogether, the research thus evaluated Moléntah's social capacity to generate value from neem processing, and achieved initial success in operationalizing neem locally.

*Neem Inventory*

The baseline neem inventory revealed 744 neem trees near Moléntah homes and surrounding fields. Just over half of the neem trees are classified as immature, indicating limited potential seed production due to size or lopping. Moléntah's largest neem trees were impressive specimens approaching 1 m DBH and 20 m height and crown; however, three quarters of neem trees measured less than half of each of these maximum measurement values, supporting the claim that Moléntah neem is relatively young. In general mature trees tended to exhibit thick versus tall trunks, often split enabling a particularly wide crown. Among the villages, Vondugu exhibited a relative abundance of neem in absolute numbers and in proportion to population and land area inventoried. Renyone and Wasanti lagged behind, with measurements suggesting that the former village's neem trees were largely planted at one time, with minimal replanting since then, and Wasanti showing fairly steady planting that has been impacted by lopping and has not kept pace with the size of the village in terms of land and population. Nonetheless, there are enough neem trees in each village for residents to work with. Overall, the Moléntah neem resource base should at least double over the next ten years as the currently immature trees reach maturity.

The inventory findings suggest an estimated range of current physical seed production from 7,320 to 18,300 kg, which could be used for agricultural application or salable product. In addition, the different forestation and tree use trends that emerged in the various villages could inform future forestry outreach and neem processing strategies. The inventory thus enables recognition and documentation of the existing neem natural resource base in Moléntah, to inform the current situation and plan for the future.

The inventory also served as a practical training experience for ten field assistants, transferring forestry field skills and demonstrating their application using locally available materials. Participation not only prepared these youth to initiate their own natural resource inquiries or support forestry outreach in the future, it also demonstrated the general value of formal schooling, particularly literacy, for working with community development projects and addressing practical community needs.

Lastly, given the paucity in the literature of morphological studies and geographic inventories of neem, this research may serve as a valuable baseline for future study of neem growth, yield, ownership, and use.

*Neem Market Paths and Value*

Although the bulk of this study focused on the neem inventory and pilot processing, identification of market products and pathways was critical to ensuring that the natural resource could translate into usable product with a socioeconomic impact. Two potential products emerged: neem seed or neem oil, largely dependent on facilitative technology available. Neem seeds are fairly easy to gather and dry; if all seeds available were collected, they could be readily used in compost to treat approximately 300-730 hectares of agricultural fields (note that Moléntah fields with neem near homes comprise only 350 hectares), or could be sold regionally to earn between five and twelve hundred thousand FCFA (about $1,100 to $2,850). Neem oil on the other hand proved difficult to extract in the Moléntah pilot, thus conservative oil yield estimates are appropriate even if a mechanical press were obtained. Neem oil is an important potential product, selling in the capital for twice the price of currently lucrative peanut oil, with conservative seed production and oil extraction estimates suggesting annual income of 1650 thousand FCFA ($3,650) and the highest estimates increasing that potential income by a factor of five. Knowing the potential neem income stream and where to sell neem products enables community members to make an informed choice in allocating their time and energy, in deciding whether that will include efforts to utilize the neem natural resource base.

### *Neem Processing*

The concluding result of this iterative action research cycle consists of a set of recommended next steps for community action around neem during the 2010 primary productive season (and beyond). Several Moléntah community members have indicated that seed gathering is currently underway;[15] for my part, I continue to research mechanical oil presses and best practices for neem processing in order to streamline the process for efficiency of time and effort. Based on this initial pilot iteration and additional review of neem processing literature, recommendations include:

1. Maintain community awareness of neem's value in order to
   - foster seedling survival,
   - identify additional markets in advance, and
   - encourage participation in seed collection
2. Gather seeds while they are available
   - primary, dry season
   - secondary, rainy season
3. Remember to rinse and shade-dry seeds immediately after collecting from ground
   - consider measuring weight and maintaining separate storage for seeds according to source tree
   - discard fruit pulp into compost pit or fields
   - consider comparing results of sun- vs. shade-dried seeds
4. Store seeds in breathable containers and only once completely dry
5. Wait three to twelve months after collection before extracting oil
6. Attempt to obtain training from relatively local neem expert
   - neem processing best practices
   - soap-making and other value-add cottage industries
7. Attempt to obtain a mechanical oil press
8. Consider whether neem cake or neem oil best suits your capabilities and needs
9. Consider whether personal use or market sale best suits your product and needs
10. Maintain contact with market buyers of neem products
11. Process seeds for oil extraction as time and technology permit
    - consider tracking the weight or volume of oil produced according to source tree and/or weight of input seeds

[15] Neem seed gathering will be affected by hunger during the 2010 dry (and rainy) season, as most Moléntah families lost the staple grain crop in a windstorm in early fall 2009. While this could serve as a motivator to earn extra cash in order to afford the already augmented cost of grain locally, lack of and otherwise directed energy related to potential malnourishment may preclude the effort.

  - if hand pressing is necessary, consider comparing results of various familiar oil extraction methods (e.g. pilot neem process, shea nut butter, *baa* nut oil, peanut oil)

12. Estimate seed and oil production according to participants and villages
13. Consider making soap or another value-added, neem-based product
14. Document lessons learned and recommended next steps for next rainy and/or dry neem season
    - consider neem plantation
    - consider inventory of outlying neem trees (*en brousse*)
      - consider training additional field assistants in field methods
    - after five years, consider another complete inventory of neem trees

*Key Takeaways*

The summer's work served as an excellent introduction for us all into the realities of neem in the Moléntah area. Local processing of neem seeds has proven feasible in Moléntah, although processing procedures and market pathways will need to be further developed to increase efficiency and income. This research cycle of inventory and neem processing appears promising despite some constraints.

<u>Participation</u>. One interesting observation involved the actual participants: even though women do not hold land tenure at the village level, they were the ones who collected seeds; in particular neem appears initially to be an activity that may benefit the income streams of older women. This apparent trend will likely clarify in the dry season when the farming labor burden is greatly reduced and all community members have more time to pursue secondary activities. Those community resources that had already experimented with or been trained in neem processing may offer invaluable insight into both external training curricula and potential local activities such as soap-making.

<u>Process Training</u>. The simplest way to shift neem from pilot to initial productive phase would be for Moléntah residents to receive sound and effective training on local neem processing. To this end, the forestry extension office approximately 10 miles from Moléntah is working with two community groups in Wasanti to submit a grant for cottage industry materials such as seedlings, presses, and soap ingredients and molds. The extension agents may also assist in inquiries to community groups already processing neem elsewhere in the country, to identify potential trainers in clear and effective local neem oil processing, as well as to solicit any other relevant information that could facilitate neem resource development by Moléntah area residents. For technical advice and assistance in the meantime, interested pilot participants can

tap nearby agricultural development projects as well as those Moléntah and neighboring residents who have had some previous experience working with neem.

Mechanical Press. Perhaps the key lesson learned involves the actual extraction of oil. The seed powder contained visible oil, but extracting it by hand with water (the traditional method in low-resource areas) proved extremely difficult, at least given the moisture level of the seeds we worked with. Although the use of locally available resources helps to ensure sustainability in community development projects, perhaps the top priority for follow-on work is to obtain (preferably in-country) a mechanical press in order to efficiently extract the oil from the seed kernel. Aided by a press, Moléntah community members are more likely to overcome the uncertainties, hard work, and risk associated with new neem activities. While incorporating crushed neem seeds into compost pits may aid the harvest, it would not necessarily generate the disposable income that selling extracted oil would.

### *Moléntah and Neem*

Neem seed harvest and processing were successfully introduced to Moléntah during this project, with an impressive community response given the intensity of agricultural work necessary during the same timeframe. I am confident that a cluster of 'early-adopters' in each village will gather neem seeds during the current dry season, and that some of them will try extracting oil. I am following up to try to obtain one or more mechanical oil presses in order to facilitate community effort to extract oil. While encouraging market pursuit, particularly until an efficient oil extraction method is identified, I also plan to emphasize the benefits of the much simpler method of crushing neem seeds and incorporating them into compost (already used by most families in some fields) in order to at least activate the systemic biopesticide benefit of neem in the area.

Neem has long provided shade and wood to Moléntah communities, but now community members have gained the capacity to process neem seeds for agricultural inputs or income generation as well. While efforts around neem will likely continue as an action learning iterative process – with plenty of learning – in coming seasons, if community members devote time and effort, neem could become a staple natural resource utilized to enhance agricultural yields and supplement disposable income to enhance quality of life in Moléntah. And even if neem continues to be primarily valued for shade, fencing, and toothbrushes, this project has served to build Moléntah community members' capacity to recognize the potential for transforming their local natural resource asset base into productive socioeconomic potential.

# APPENDICES

## *Appendix A: Semi-Structured Interview Sample Questions*

<u>For community members</u>

Please describe the current agricultural activity in the area – trends over time, crops planted, inputs used, difficulties encountered.

What do agricultural inputs such as fertilizer and pesticides sell for currently, which ones are used in the community, are there preferences, how are such decisions made (to use inputs and which ones)?

What role do trees play in agricultural activity and general daily life? Are any trees particularly useful or important?

Is anyone here familiar with the neem tree? In what ways (i.e. is anything in particular known about the neem tree)?

Where are neem trees located in this area?

Who owns the neem trees in this area – does that include the entire tree or certain parts?

What do community members use the neem tree for?

Has anyone heard that neem can be used for a variety of uses such as soap making, agriculture, and health?

Has anyone ever used neem in these contexts? In what ways? How did this come about?

Is anyone interested in learning more about neem processing with the goal of home use and/or potential income generation?

Are there particular products that elicit the most interest in learning to produce?

Would production be preferred for potential home use and/or local sale and/or regional sale and/or export?

Does this group already have access to neem trees; if not, how would you like to gain access?

Does this group have access to land to raise neem trees?

What community group structure would you like to use to manage any activities around neem?

For foresters/merchants & community members

Are neem products currently available in the market or through state extension?

Which products are available?

Who produces these products?

Who buys these products for resale?

What does the supply chain look like for neem products (i.e. village groups to middlemen to exporters? etc.)

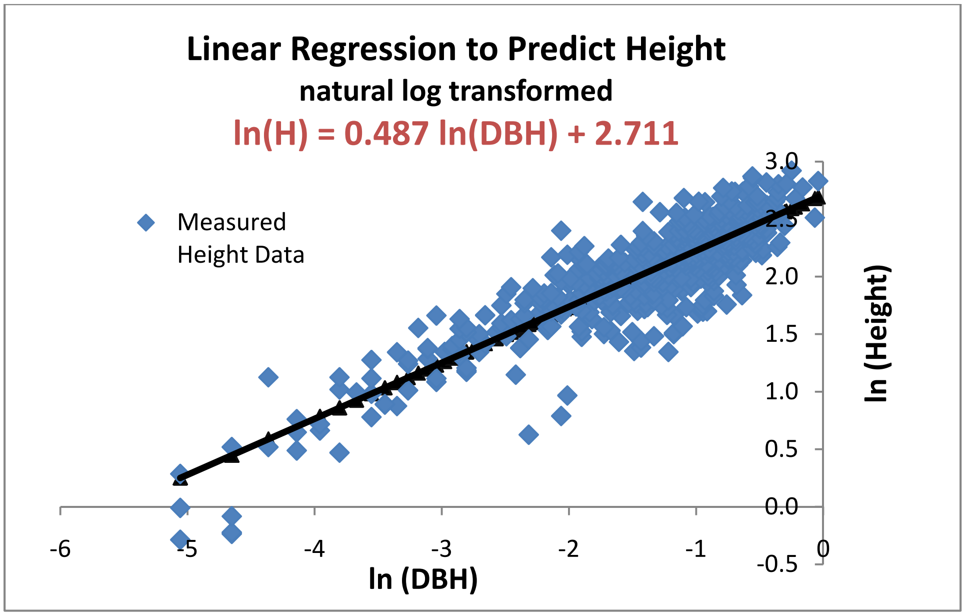
What do agricultural inputs such as fertilizer and pesticides sell for currently, which ones are used in the community, are there preferences, how are such decisions made?

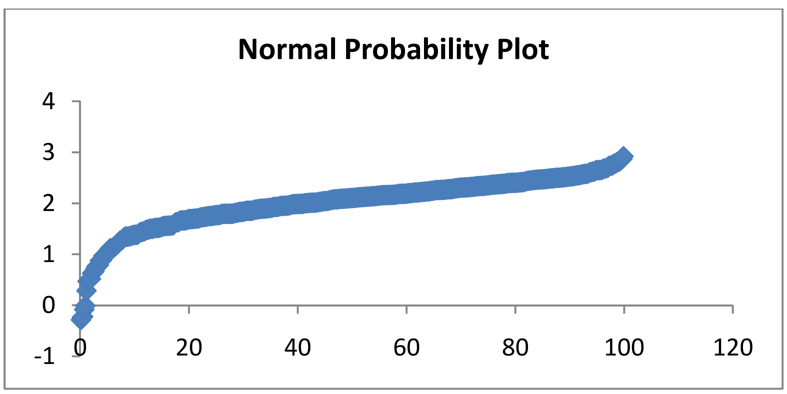
Would you be willing to sell neem as a natural alternative to chemical pesticides and fertilizer?

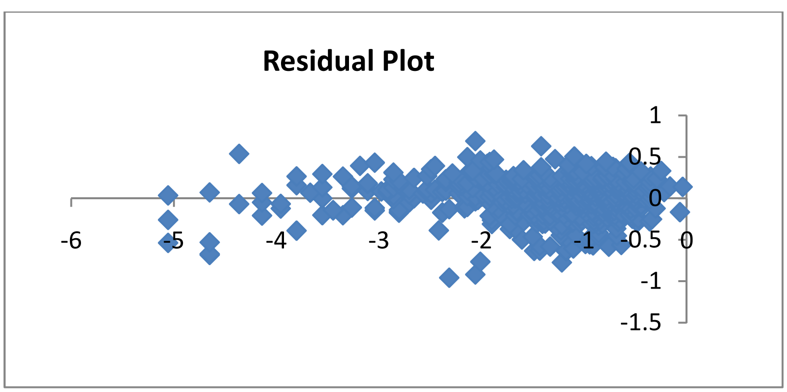
What neem products are merchants interested in?

Do you know of any importers/exporters of neem products?

### *Appendix B: Regression Results for Neem Tree Heights*



| *Regression Statistics* | |
|---|---|
| Multiple R | 0.878135342 |
| R Square | 0.771121678 |
| Adjusted R Square | 0.770646827 |
| Standard Error | 0.244192699 |
| Observations | 484 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 96.83462 | 96.83462 | 1623.922 | 1.9E-156 |
| Residual | 482 | 28.7417 | 0.05963 | | |
| Total | 483 | 125.5763 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 2.711462846 | 0.020763 | 130.5914 | 0 | 2.670666 | 2.75226 |
| -5.056752891 | 0.486750316 | 0.012079 | 40.29792 | 1.9E-156 | 0.463017 | 0.510484 |

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