EXECUTIVE SUMMARY, EXCERPTS AND CONCLUSIONS OF

An assessment of Coconut Lethal Yellowing-type Disease (LYD) in Mozambique, November 2006

Consultant's report by

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Executive summary

This report describes a mission to Mozambique, with a visit to Tanzania en route, to review the current status of lethal yellowing-type disease of coconut palm (LYD), its likely impact on the local economy in Central Mozambique, and possible measures to control it. The disease-affected area in Zambezia has expanded considerably since last survey in 2003 and new foci are present in Nampula. However, rates of spread have been considerably slower than those experienced for LYD in the Caribbean region, encouraging the view that the disease might be controlled by phytosanitary measures. Overall, about 5% of the total coconut area of Zambezia is probably now affected but many areas have completely lost production. At present rates of spread, it is likely that more than 50% of the coconut area will be lost within next 9 years. Unless urgent measures are sustained over a large scale, coconut cultivation will effectively cease within large areas of central Mozambique, with the loss of export earnings and rural livelihoods, including key components of household income, nutrition and shelter for over 1.3 million people in coastal Zambezia. Whilst impact of the disease will be felt well beyond the coastal belt, little evidence was obtained to support the view that LYD threatens to bring about an overall decline in regional productivity in the province.

Short-term control measures include surveillance and scouting to detect early cases of disease; prompt eradication of diseased palms (by cutting and burning); replanting with selected seedlings from local Tall coconut types (some of which appear to show a measure of resistance); together with under- or inter-planting with alternative crops and, in areas that are not yet affected by disease, measures to raise the productivity of existing palms and add value to coconut products. Management strategies need to be tailored to different stages of the disease epidemic and are likely to be most effective at, or in advance of, the margins of active spread of disease. It is thought that about 35% of individual palms within populations of the local Tall coconut variety survive even prolonged exposure to LYD but these are vulnerable to damage from high populations of rhinoceros beetle that breed in dead palm trunks and can kill off survivors. There is thus a need for collective and continuous action - by all growers and over a sustained period - not just to prevent infection moving from diseased to healthy palms but also to remove and destroy dead palm trunks. Smallholders alone are unlikely to be able to cut down and dispose of dead and dying palms or to produce replacement seedlings on scale required, but this could be achieved through a coincidence of interests between government, smallholder and private sectors in implementing large-scale control. Examples are given of public-private partnerships that could be scaled up and would have a positive rate of return within a five-year timescale.

Urgent action is required. The rapid advance of LYD means that there is now only a limited window of opportunity for intervention before the disease overwhelms coconut cultivation in central Mozambique and the livelihoods that depend on it.

1. Disease distribution and spread

1.1. Coconut cultivation in Mozambique

1.1.1. The coconut palm (*Cocos nucifera* L.) is grown along much of the coastal belt of Mozambique but the largest plantings are in the provinces of Zambezia, Inhambane, Nampula and Cabo Delgado.

1.1.4. Mozambique is the largest producer and exporter of coconut products and has the second largest area under coconut in Africa (after Tanzania where a higher proportion is used purely for domestic consumption). Coconut is thus a valuable domestic and export commodity but its volume has declined in recent years owing to a combination of biological, social and economic constraints. Of these, lethal yellowing-type disease (LYD)[1] is the most serious because of both the direct damage to plantings and also the uncertainty and loss of confidence in investment in replanting and rejuvenation of the large populations of older palms.

[1] The term "lethal yellowing" was originally coined for a disease of coconut palm in Jamaica. Diseases with similar symptoms in Africa and Asia are now known to be associated with genetically different strains of phytoplasmas so the term "lethal yellowing-type disease" (LYD) is preferred in these regions.

1.2. History of LYD in Mozambique

1.2.1. Diseases now recognized as LYD have been known in East Africa (Tanzania) for 100 years and the first reports from Mozambique are usually attributed to Carvalho and Mendes in 1958 (from Cabo Delgado), and Quadros in 1972, from Moruba, Zambezia Province (see Schuiling & Mpunami, 1992). A joint survey carried out in 1995 by the Department of Plant Protection of the Ministry of Agriculture & Rural Development of Mozambique (DSV) and National Coconut Development Programme of Tanzania (NCDP), using DNA-based diagnostic techniques available at that time, confirmed the presence of phytoplasmas in samples from Cabo Delgado similar to that found in Tanzania and Kenya, but subsequent examination of samples from Zambezia using more discriminatory molecular techniques showed that characteristics of the presumed pathogen differed from those in Tanzania and Kenya and bore a closer resemblance to strains from West Africa (Mpunami *et al*., 1999).

1.2.2. Alarm about the present outbreaks derives from detailed surveys carried out after identification of LYD on the Madal Estates in the late 1990s (Figure 1b). Madal management, working with CIRAD scientists, continued to monitor spread of the disease and developed a comprehensive control and rehabilitation proposal (Anon 2000). A project (PASCOM) based on these proposals was funded by the French Development Agency (Agence Française de Développement; AFD) in 2001/02, but unfortunately funding was discontinued after about one year owing to perceived management problems with the implementing company. Data on distribution of the disease in Zambezia from this scoping study served as a baseline that was updated during the present mission, as shown in Figure 2.

Current distribution of LYD

***1.3.1. Zambezia*.** Information was obtained from the management of Madal and Geralco Estates and verified by field visits to Inhanssunge and Macuse. No additional information was available from the DPA (the Zambezia regional director of agriculture was not available during the consultant's visit). Main findings are:

- there has been continued active spread of LYD in the coastal coconut belt to SW and NE of Quelimane, but substantial areas still remain free of the disease including the Malayan Dwarf seed garden at Macuse
- at least two new districts have been affected since 2000 and there are many new foci in previously-affected districts
- despite this, the overall percentage losses by district are still low (see Table 2); however, a combination of LYD and rhinoceros beetle (*Oryctes monoceros*) have caused near 100% loss at the original foci and widespread loss of productivity.

1.3.2. Nampula. Information was obtained from technical staff at the DPA Office in Moma and at Boror Estates, Ligonha (the Nampula regional director of agriculture was not available during the consultant's visit). Staff at Moma have carried out some recent disease surveys in Moma but had heard reports of disease in other districts; however, no written reports were available. The main findings are:

- disease foci are known to have been present in Moma Sede and Larde since 2001 but probably became established earlier
- there is no precise information on the extent of disease but 11,761 diseased palms have already been cut down in Moma Sede under a PROAGRI programme (which currently operates only in Moma)
- 12,500 palms (about half) have been affected by disease in one block on Boror estate at Ligonha (this probably includes palms damaged by rhinoceros beetle)
- new foci are reported at the bay of Angoche (Sicupire), 13km from Angoche at Mamaripe, and at Sangage (Nantapa, Mulaenda and Topa, 43km from Angoche)
- the disease is thought to be present in the plantation at Mogincual district and there are hearsay reports from the plantation at Quinga.

1.3.3. Cabo Delgado. It was not possible to visit Cabo Delgado in the time available and no information was obtained from DPA or other government sources. The following information was obtained from other sources:

- major epidemics were reported from Mocimba da Praia and Pemba regions in late 1990s and investigated by Mozambique authorities working with NCDP (Tanzania) scientists
- satellite photographs (Google Earth) suggest only a few mainly scattered coconuts remain along coastline; however, high resolution images are lacking for parts of area including offshore islands
- The owner of the plantation on Quirimba Island (800ha mature coconuts, about 8km offshore) reports sporadic cases attributed to LYD (about 2-3 palms per annum) and considers that the low incidence is maintained through prompt removals.

1.3.4. Other provinces. No LYD has been reported so far from Inhambane or other provinces. Quarantine measures, including checkpoints at key roadside locations, are in place to restrict movement of coconut planting materials from north to south.

Figure 2a. Current distribution of LYD in southern Zambezia

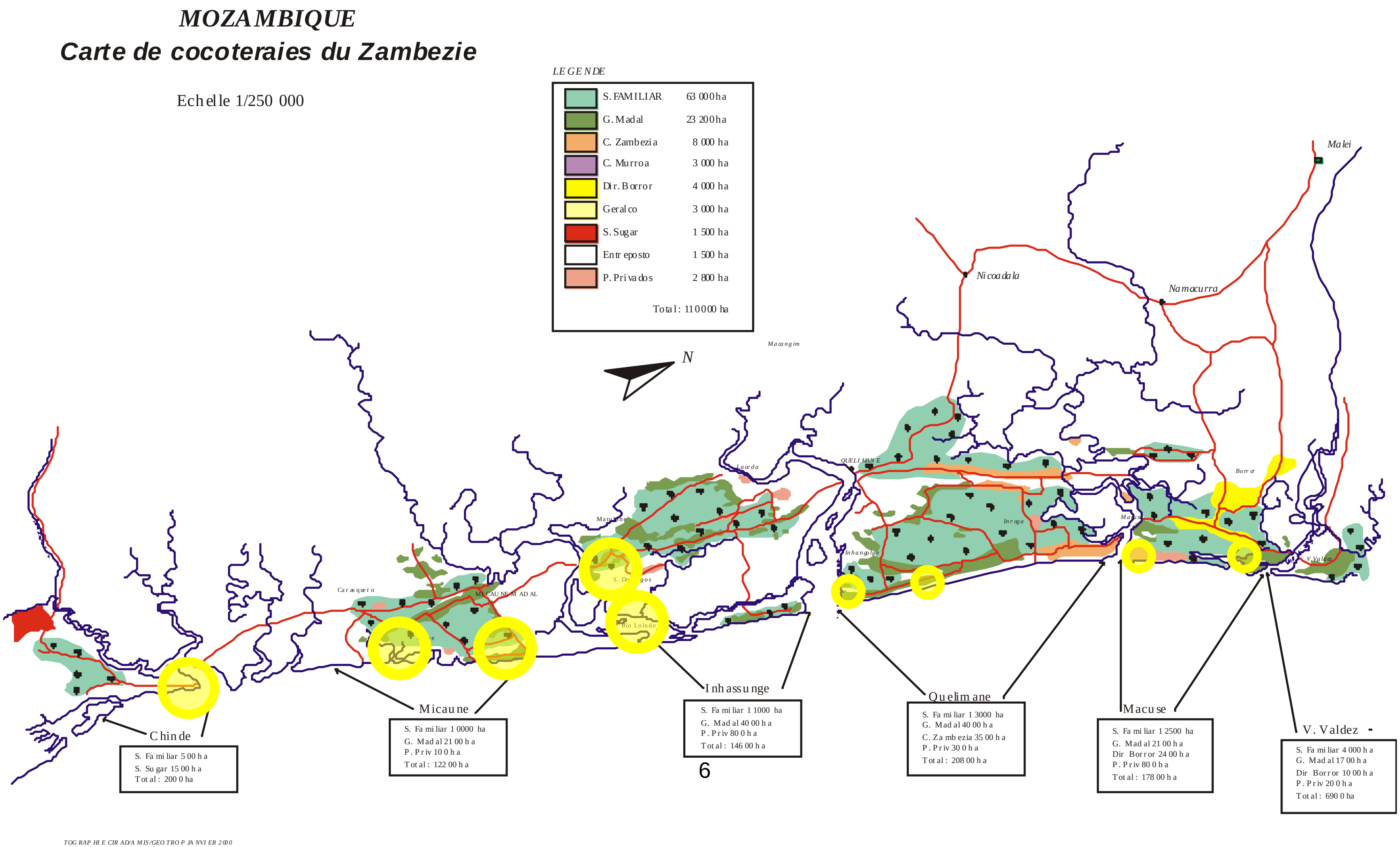
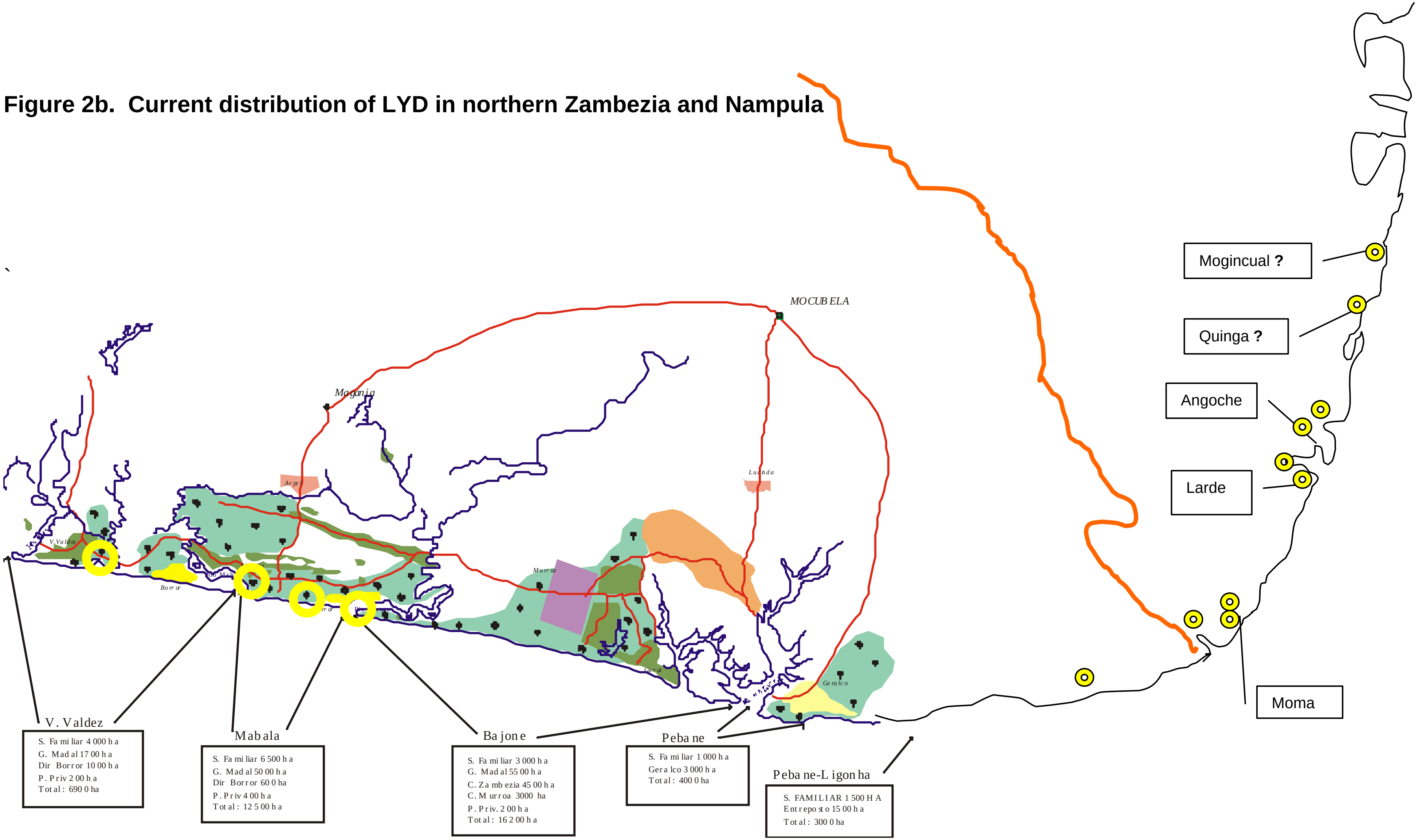


Figure 2b. Current distribution of LYD in northern Zambezia and Nampula



1.4. The future spread of LYD

1.4.1. As several authorities have noted, the spread of LYD in both East and West Africa has been much less predictable, and has usually been much slower, than that of outbreaks in the Caribbean region. In Jamaica 90% of an estimated population of six million coconut palms were lost in between 1961-1981; 75% of palms were lost in Key West, Florida between 1955-1960; and 75% of palms in greater Miami area between 1971-1975. In contrast, mean cumulative losses in Tanzania were estimated at 8.5% between 1975-1991 in northern distracts and 55.6% between 1965-1991 in southern districts, where the disease has tended to spread more quickly and amongst a wider range of varieties (Schuiling *et al*., 1992). Estimates of between 1-15% disease incidences over a five-year period of observation in coastal districts of Zambezia thus compare more closely with those in Tanzania than those in the Caribbean.

1.4.2. Plant disease epidemics can be characterized and compared by their apparent infection rates which, in their simplest form, are described by the relationship:

$$dx_t / dt = r\, x_t (1 - x_t) \qquad [1]$$

where the change in proportion of disease, x, with time, t, is proportional to an apparent infection rate r. Values of r can be used to compare the rapidity of spread of different epidemics and, subject to certain limitations, to predict future losses. Rearranging equation 1,

$$r = \frac{1}{t_2 - t_1} \cdot \left\{ \ln \frac{x_2}{1 - x_2} - \ln \frac{x_1}{1 - x_1} \right\} \quad \text{or} \quad r = \frac{1}{t_2 - t_1} \cdot \ln \left\{ \frac{x_2 (1 - x_1)}{x_1 (1 - x_2)} \right\} \qquad [2]$$

where x_1 and x_2 are the proportions of plants affected at times t_1 and t_2 respectively and *ln* are natural logarithms (=$\log_e$). Hence it is possible to calculate values of *r* from disease incidence data measured at two time intervals and thence to calculate the theoretical disease incidence at a future time.

1.4.3. Using data from Table 2, values of *r* from Zambezia range from 0.016 in Maquivel Quelimane to 0.040 per month in Micaune. These are comparable to *r* values (per month) calculated from northern Tanzania (0.02 - 0.07; Schuiling et al., 1992) but considerably lower than those reported by McCoy (1976) for Florida (0.15-0.42) and Jamaica (0.15-0.30). In reality, there is evidence that LYD *per se* kills only about 65% of populations of mature East Africa Tall palms, the remainder usually succumbing to damage caused by high populations of rhinoceros beetle that breed in trunks of old and dead palms.

1.4.4. If one makes a brave assumption that the values of *r* remain constant throughout the LYD/rhinoceros beetle epidemic and assumes that there are no effective interventions to control spread, then taking a mean *r* value of 0.028 and a current overall disease incidence in Zambezia of 5%, future losses for the whole province will reach 50% within another 8.8 years. Clearly, unless urgent action is taken, then commercial-scale cultivation will cease to be viable and smallholders will suffer severe loss of livelihood long before that time.

1.5. General observations on coconut in the disease areas

1.5.1. As noted above, rates of spread in Zambezia are relatively low compared with rates of spread in other countries, including parts of southern Tanzania and the Caribbean. This encourages the view that the disease might be controlled by early removal of diseased palms and by replanting with selected local coconut types that appear to show reduced susceptibility. Factors that need to be taken into account in considering and planning a control campaign include:

- Smallholdings tend to be more severely affected than large plantations, but this may be due to the mixed aged structure of many smallholder plantings. Estates tend to replant in blocks and to have a more uniform age structure.
- It appears that 35-40% of palms within populations of the local Mozambique Tall (MZT) can survive prolonged exposure to LYD, either due to resistance or escape, but the survivors are usually weakened or killed by high populations of rhinoceros beetle that develop in the dead trunks unless these are removed and burnt.
- Surviving Tall palms appear more likely to exhibit a green, rather than bronze or brown, phenotype. Similarly, the green phenotype of Malayan Yellow Dwarf (MYD) x MZT hybrids appears more likely to survive exposure to disease than other colour forms, although all are more susceptible than the MZT. Similar observations have been noted in parts of Tanzania for populations of the local East African Tall (EAT) variety, which probably shares the same origins as the MZT.
- Based on these observations, seedlings derived from surviving MZT palms and selected for green phenotype currently appear to offer the best choice of planting materials. For the time being this is a “best bet”, and in the absence of controlled experimental testing new plantings should be monitored closely and compared with similar plantings of unselected materials in farmers’ fields.
- Coconut palms on both estate and smallholder plantings suffer from old age, poor maintenance and low productivity but no other crop can adequately substitute for coconut within the coastal belt cropping system.
- Given the magnitude of the problem, the scale of measures needed to remove dead trunks and to produce selected replanting materials (let alone to produce, process and find markets for alternative crops for much of the land presently under coconuts), a very substantial mobilisation of resources and investment is required across both estate and smallholder sectors to save the crop and its associated industry.
- The present general lack of confidence in investing is exacerbated by both biological constraints (LYD and the associated rhinoceros beetle problem) and, in the estates sector, by social problems, notably high incidence of theft and concerns that minimum wage legislation may

reduce incentives and discourage productivity. Partnerships between the public, private and smallholder sectors, working together to maximize their relative strengths, offer the best and perhaps the only hope of revitalizing the industry.
- In the longer term, field testing of introduced varieties and hybrids must be done in order to identify alternative sources of resistance to LYD that can be used to develop planting materials adapted to local conditions.

2. Impacts of disease and associated factors

2.1. A detailed analysis of the importance of coconut for the rural and national economy in Mozambique is set out in the PASCOM project scoping report (Anon 2000). Roughly translated, the conclusions were as follows:

- "The development of lethal yellowing disease … threatens, in time, the very existence of coconut cultivation in Mozambique. In the absence of curative or preventive treatments, the eradication of diseased trees followed by replanting of tolerant varieties remain the only means of fighting this phenomenon and of avoiding a fatal outcome.
- Coconut is a cultivated plant of enormous social and economic interest to populations in the zones concerned. This resource, which represents the principal source of income and comprises an essential part of the diet for these populations, is the one best adapted to soils and climate of the coastal zones and is often the only crop that can be grown there. Its disappearance would have important negative effects and, conversely, its revival will contribute to improved incomes and livelihoods for the families concerned.
- The cultivation of coconut, a traditional activity in Mozambique, remains little developed today whereas it could play an important part in the national economy, so as to meet essential needs for the inhabitants (oils and soaps), as well as export activities, able to procure foreign exchange from copra, oils, grated coconut etc."

2.2. Although very little data on the direct impacts of LYD on the rural economy could be obtained within the timescale of this mission, there was considerable indirect evidence of this:

- coconut palms have now virtually disappeared from the most severely affected areas, and in many cases only a small fraction of the land under both estate and smallholder ownership is being cultivated now
- the range of alternative crops being grown by smallholders is very limited and produce tends to be highly seasonal: mainly cassava, some sweet potato, pineapple, occasionally bananas, and short duration crops such as beans, groundnuts, okra and tomatoes
- for the time being, some villagers are able to find alternative employment by traveling further afield but the rate of youth migration to urban areas is said to have increased
- Madal reported that they had to suspend buying and processing of copra, resulting in loss of US $2.2m of income per annum to their workers and suppliers (in fact, Madal and Geralco believe that losses to

praedial larceny exceed those due to LYD by a factor of at least two to one).

2.3. Using data obtained from the national census (1997) and updated to allow for subsequent population growth, Table 2 attempts to translate LYD into losses of domestic production (for consumption or sale). All families probably consume, or prefer to consume, at least one coconut per day so the data suggest that losses in the two most severely affected districts are already at or approaching this level. In financial terms the loss is relatively small - a fresh coconut is currently worth about 1Mtn so the yearly cost of a daily coconut is about US $14. However, the highest total annual production per family of 3550 nuts (Inhanssunge) represents a significant annual income from domestic production, of US $140 for little effort and virtually no outlay. To this can be added opportunities for earned income from the estate sector.

2.4. These data indicate that the total area lost to LYD is now estimated to be 5,030ha, or about 5% of the total area in Zambezia. The magnitude of losses in Nampula and Cabo Delgado is unknown.

Table 2. Annual losses due to LYD in the coastal coconut belt, Lower Zambezia, 2006 (data from Madal)

District	Administrative unit	Estimated population (x1000)	% loss	Estate area lost (ha)	Smallholder area lost (ha)	Coconuts produced per family (No./year)[1]	Coconuts lost per family (No./year)
Chinde	Chinde	161	4	60	60	2050	277
	Micaune		15	255	1425		
Inhanssunge	Inhanssunge	109	10	170	1290	3550	355
Nicoadala	Maquival Quelimane	435	3	222	402	924	28
Namacurra	Macuse	201	4	180	532	1985	79
Maganja da Costa	Vila Valdez	286	1	23	46	1584	16
	Mabala		1	55	70		
	Bajone		1	117	35		
Pebane	Pebane	168	1	30	20	536	5
	Naburi		1	20	10		
TOTAL		1360	5	1132	3890	1515	86

[1] Assumes 1ha of smallholder coconut consists of 100 palms producing 60 coconuts per annum and one family = 5 persons

3. Measures to address the disease and associated problems

3.1. Past and present activities

3.1.1. Comprehensive proposals to mitigate the effects of LYD and the associated *Oryctes* infestation, and to rehabilitate under-productive palms in disease-free areas, were prepared by CIRAD for the PASCOM project scoping study (Anon, 2000) and these are outlined in a MINAG Coconut Sub-Sector Plan (2005). Similar measures are now being advocated in those areas of Tanzania that are expected to experience less rapid spread of LYD. Although few if any of these measures have been subjected to statistical evaluation in controlled experimental trials, there is a considerable body of observational and indirect evidence that they will slow down (and in some cases have stopped) spread of the disease, and with it, the associated beetle damage.

3.1.2. In the consultant's view these are, at present, the "best-bet" options for controlling the disease and the only short-term measures that can and must be done not just to save the industry in northern Mozambique but also to safeguard plantings in the south of the country. That said, it has to be realized that elements of control of LYD can be location-specific and in some cases controversial. Aspects of control and further background information about the biology and ecology of LYD are provided in Appendix 3.

3.1.3. Implementation of these and other control measures was commenced under the AFD-funded PASCOM project, and 120,000 diseased or dead palms were cut down before most activities had to be suspended following its early demise. A GTZ public-private partnership project, with Madal Estates, is sharing the costs (50% each) of cutting out diseased /dead palms and providing selected green MZT seedlings for 100ha of smallholders in Gonhane and 200ha in Micaune (see Section 4 for cost-benefit analysis).

3.1.4. Madal, Geralco and probably other estates recognize the importance of these measures and are committed to implementing them within the constraints imposed by lack of resources and an uncertain outlook for investment. On its own plantations, Madal is attempting to cut all LYD-affected trees, has replanted 300ha with green MZT in 2006 and plans to replant a further 500ha between January-April 2007. **However, unless similar measures to reduce infection are implemented within neighboring smallholder plantings then the effectiveness of these measures will be severely compromised.** At present there is little evidence that smallholders are able or prepared to do so without external assistance and/or incentives.

3.2. Disease zones and future control strategies

3.2.1. Given the magnitude of the LYD problem and the shortage of resources to address it, it is important to assign priorities for control activities. Disease epidemics can be considered to have three zones within which the impact of management practices will differ. This is illustrated diagrammatically in Figure 3 and summarized in Table 6. In the *risk zone*, the priority is exclusion - to detect and eradicate any new infection as quickly as possible. Priorities for the *epidemic zone* are to contain the disease and try to limit further spread, whilst in the *endemic zone* it may be necessary to adopt strategies for coping or living with the disease whilst giving priority to eradication at the front line. Clearly, the boundaries are dynamic and become blurred by disease spread from existing outbreaks and the development of new foci, but the objective is to reduce the size of existing epidemic zones and to prevent new ones becoming established. The intention here is merely to give focus to the control strategies that are discussed in the next section.

3.2.2. It is of course important here not to lose sight of the longer term, and especially the need to move towards coconut varieties that have resistance and improved productivity, and planting systems such as mixed or diversified cultivations that are less vulnerable to LYD. This applies not just to provinces in northern Mozambique where the disease has become established but also to planting in the south where the disease is not yet present. As recognized in the draft coconut research strategy (MINAG 2005), there is a strong case here for collaborative regional research in order to pool knowledge, to share diagnostic facilities and expertise, and possibly also access to germplasm (a global coconut collection made by NCDP in the 1980s was replicated in Zanzibar, which is still considered to be free of LYD, and might be made accessible to Mozambique).

Figure 3. Zones of disease epidemiology

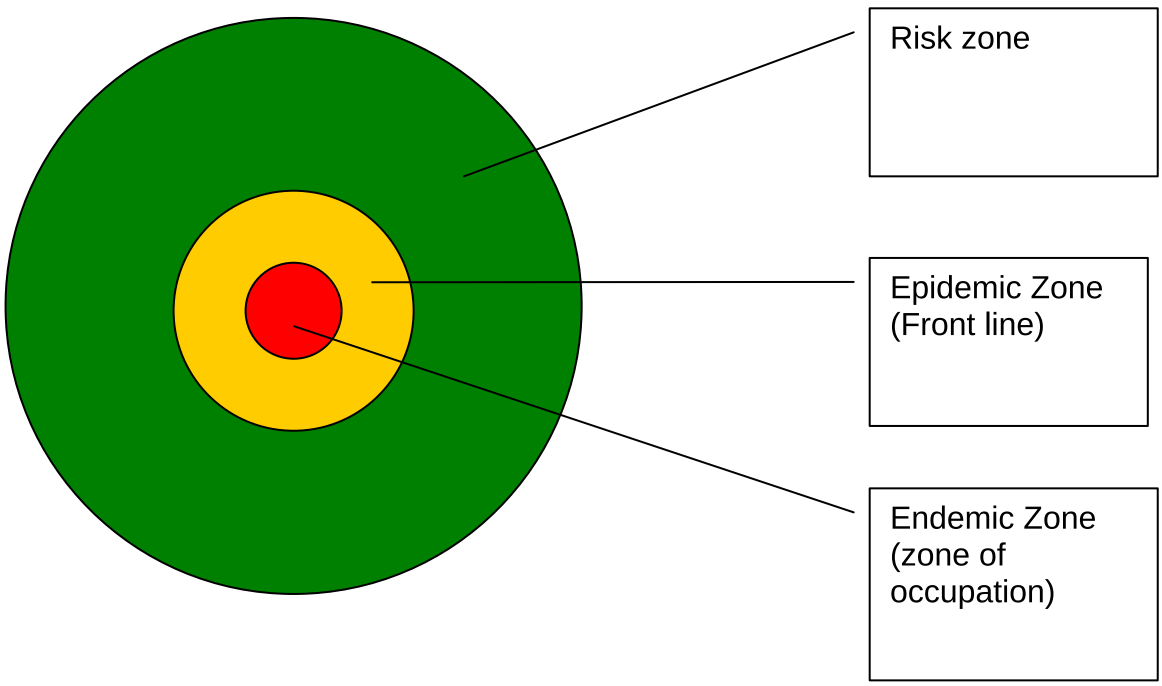


Table 6. Priorities for control campaigns

0 (none), 1 (low) – 3 (high)

Activity	Low risk zone	High risk zone	Epidemic zone	Endemic zone
Vigilance and public awareness	3	3	1	0
Active scouting for early detection	0	2	3	0
Quarantine	3 (movements in)	3 (movements in)	3 (movements in and out)	3 (movements out)
Immediate removal of whole diseased plants including trunks	3	3	3	0
Removal of dead trunks followed by replanting coconut (free/subsidised selected seedlings as incentive?)	2	0	0	3 (when free of LYD!)
Plan and promote alternative crops	0	1	3	3
Plant alternative crops	0	1	2	3
Improve existing production	3	2	0	0
Support for livelihood diversification	0	0	2	3

4. With/without funding scenarios

4.1. Without funding

4.1.1. The “without funding” scenarios can be extrapolated from Section 2. In the absence of funding for control and rehabilitation, LYD will continue to spread. Without outside interventions, commercial-scale copra and oil production will probably cease within 5-10 years, with consequent loss of domestic and export production and the employment, rural investment and services that this generates. Smallholders will also cease to be able to produce coconuts over an increasingly large area, with few if any alternative crops to take their place. Consequences will be increased rural poverty and probably migration from the land. Increasing scarcity will most likely lead to increasing prices which may in turn encourage production of coconut in other areas, but this could lead to marginal land that is presently under coconut going out of production altogether, and increased pressure on land that is better suited to other crops. Some of the more promising “with funding” scenarios have already been prepared and are being, or have been, implemented by others. These are presented and discussed below.

4.8 Summary of with funding scenarios

Target zone/ project	Brief description	Total cost and expected outcome
Endemic zone: Rehabilitation of coconut-based cropping systems	Modeled on existing GTZ Public-Private Partnerships project. *Objectives:* To help smallholders to clear their land of dead palms, replant with selected MZT seedlings and alternative short-term crops. Benefits extend to estate sector through area-wide clean up of pests and disease, stabilizing livelihoods of local communities, increased product availability, services to project. *Main activities:* Define and delimit area(s) of operation; raise awareness and mobilize community groups; cut and burn dead and dying palms; clear land ready for planting; source coconut seed, establish nurseries, select and distribute seedlings; source, procure and distribute other planting materials; monitor progress and evaluate outcome. Consider a pre-project desk study to investigate alternative uses or means of disposal of coconut wood. *Partners:* Government, private estate sector, NGOs, CBOs, farmer groups, external technical inputs desirable.	Total cost US$528,000 for about 4000 smallholders (US$132 per smallholder), but probably higher allowing for mechanized cutting out. Positive return on investment from coconut alone within 12 years but much shorter allowing for short-term crop production. Target indicators over 5yr period could be percentage of young palms reaching a given development stage.
Epidemic zone and new outbreaks in risk zone: Early detection, eradication and replacement	Modeled on previous PASCOM project scoping study report. *Objectives:* To control spread of disease by prompt removal and destruction of infection sources and provision of new planting material. Targeted at smallholder sector but benefits extend to whole country through slowing spread of disease. *Main activities:* Raise awareness, mobilize villagers and establish “monitoring brigades” as surveillance and rapid reporting systems to allow prompt eradication of diseased trees. Confirm disease, advises villagers, destroy palms, and compensate farmers with a free replacement seedling for each diseased tree removed (this might need to await evidence that disease brought under control and risk of re-infection reduced). Estates and NGOs produce replacement seedlings. Record and monitor control interventions; subject results to epidemiological analysis to assess impact and improve methodologies. Overall strategy to start with isolated	Assuming total affected area now 6000ha, and 15% inflation since 2000, estimated total cost now US$6.0m over 5yr, safeguarding about 20,000ha of smallholder plantations, value US $2.4m pa from year 6 onwards or cumulative value US $4.8m over 5yr duration of project; and positive net return after 6 years allowing for ongoing

	cases or small foci and then work backwards towards main epidemic zone. Dead palms left *in situ* unless or until replanting. *Partners:* Government, private estate sector, NGOs, CBOs, farmer groups, external technical inputs to establish and trouble-shoot early detection techniques. *Observation*: An early diagnostic test could be used to detect pre-symptomatic "contact" palms, improving efficiency and speed of bringing spread under control (see postscript, para. 7.1).	annual costs of about US $300,000 that might be required for continuing control of spread.
Risk and epidemic zones: Integrated Coconut Development Programme proposed by Boror Agricola SARL, at Maquival Plantation	Proposal from Geralco provides example of innovative systems to share stewardship of estate land, diversify production and add value to products. *Objectives:* To enhance productivity from 45 to 140 nuts/palm/year by irrigation, manure, vermiculture, and management of pests and diseases, planting high-yielding coconut seedlings over an area of 200 hectares; to containing LYD on both estate and adjacent smallholder plantings, and generate employment. *Main agronomic activities:* Plant high yielding coconut seedlings; cut and remove of LYD-affected palms; establish bore wells; set up drip irrigation systems; raise and plant jatropha; establish rice demonstration and research farm; intercrop coconut; test antibiotic treatment against LYD; and micronutrient injection in coconut. *Main management innovations:* "*Persela*" system: 200ha distributed to 35 families (500 to 1000 palms each) on a long-term contract basis. Families live on-farm, take care of plantation, collect and sell coconuts to Boror Agricola at negotiated rate (slightly discounted from prevailing market rate. Subject to consultation, lessees are permitted to intercrop the land for their sole benefit. "*Guarda*" system: company employees are each allotted 1000 trees, paid a normal salary, are responsible for the guarding and maintaining the palms, and become eligible to receive a bonus, on top of salary, based on the number of coconuts delivered. They also receive any benefits from intercropping. Both systems are helping to reduce theft, improve participation, land availability and incomes. *Partners:* Initially Boror Agricola (Geralco), their employees and local communities.	Estimated cost: US $713,000, with a cost-benefit ratio of *x* 3.2 over 5 years.

Low risk zones: Raising the productivity of existing healthy palms	Modeled on previous PASCOM project scoping study report. *Objectives:* To improve the productivity and yield of existing ageing and under-productive palms in smallholder plantings ("intensification"). *Activities:* Select intensification sites based remoteness from LYD foci, age of palms, and motivation of growers. NGOs organise farmers into village associations and obtain undertakings from growers in return for subsidised fertilizers for 3yr, after which farmers finance from increased production. Support with demonstration trials and training for extension personnel. *Partners:* Farmer groups, NGOs, Madal and/or other estates, external technical input. Observations: Other benefits would include improved capacity to monitor and respond promptly to any new disease outbreaks, improved soil fertility for under- or inter-planted crops, and greater interest in, and maintenance of, coconut.	Estimated cost (yr 2000 prices x 15%) = US$ 3.8m for 6,000ha, reaching 8,000 growers. Expected outcome increase in net income of *x* 2.2 per ha over 5 yr; rate of return 27% over 20yr taking account of costs of providing subsidized fertilizers for 3yr or real rate of return to the farmer (*i.e.* excluding the cost of subsidized fertilizer) 237%.
Risk zones, and those epidemic zones where control measures applied: Improved processing and added value products	Modeled on previous PASCOM project scoping study report. Objectives: To enable smallholders to benefit from improved productivity of coconut processing and hence add value to their existing coconut plantings and provide additional incentives to attempt to control the disease. *Activities:* Improve copra drying through the provision 300 improved driers for 5 individual growers and 17 improved collective driers for groups of 30, total 2000 growers, Introduce village-level oil extraction, to improve amount and quality of coconut oil through provision of 20 units producing 25 litres/day and 2 units producing 200 litres/day. Introduce oil extraction by "fry-drying" fresh coconut meat (this requires re-evaluation against production of virgin coconut oil as a possible alternative). *Partners:* Farmer groups, NGOs, local private sector entrepreneurs, external technical support (CIRAD)	Total cost US$455,000 over 5yr (2000 prices +15%), giving anticipated net increase in annual income of US $75,816
Other interventions	Other scenarios to help safeguard, diversify or improve profitability of the coconut industry could include: • A program by ORAM to establish cooperative enterprises for small farmers growing	Need to be defined and costed

	coconut, maize and rice, to facilitate investments in processing machinery and to improve linkages with markets • Development of added-value products such as virgin coconut oil, desiccated coconut, coir dust (fibre and coco-peat), diversification into jatropha, conversion of jatropha and coconut oil to biodiesel. These would open up a larger market for both estate and smallholder produce. • Potential market (and hence investment) opportunities to be derived from both the amenity and environmental value of coconut to tourist industry. • Potential interest in coconut (re)planting for carbon offsetting and investment opportunities from carbon trading (see postscript).	
Research	This should be considered on a **regional basis** and priorities would include: • Resistance screening, especially planting out, maintenance and monitoring of exotic germplasm introduced under PASCOM and COGENT projects; possible introduction of new germplasm from Cote d'Ivoire and Zanzibar. • Development of practical techniques for early detection and diagnosis, including investigation of pathogen characterization and variability. • Epidemiological analyses in support of large-scale control operations. • Investigation of disease transmission and possible control of vectors, for instance through management of alternative host plants.	Need to be defined and costed

5. Conclusions

5.1 As noted above, the estate sector is already struggling to maintain the viability of coconut plantings and commercial-scale copra and oil production in the face of mounting losses from LYD and from theft of produce. Some diversification is already taking place (and there are doubtless other plans in commercial confidence) but the scale of the problem is huge and the investment outlook is poor. Unless efforts are made to change this, the outlook does not look hopeful. Investment on such a scale is unlikely to come from public or donor sectors, let alone from small farmers themselves although the latter may be able to play a greater role. The consultant would thus argue that public and private sectors have key roles to play and strong efforts will be needed to encourage this, including supporting a facilitating environment that tackles the social and economic, as well as the biological, problems that are presently undermining the industry.

5.2. This is not the place to discuss the economics of growing coconut, or the markets that determine this. However, it would be sensible to review the future role of coconut in the Mozambiquan domestic and agro-industrial economy. Both estates and smallholders are living off past investments. Are both willing to re-invest in reviving the industry, and how (and by whom) are the associated risks going to be managed in order to ensure that investments are made for the future? It is suggested that this requires not necessarily a desk study but a more participatory process, such as a working group or a carefully moderated electronic discussion forum, to agree objectives and to plan a way forward.

5.3 It was not part of the consultant's brief to consider the role of, or need for, research on coconut in general and LYD in particular. However, it is essential to maintain and carry through research to identify and exploit sources of resistance to LYD. Any short-term disease management program should accept responsibility to support these medium-to long-term research objectives and to promote plans for their continuation. At this juncture, it is worth noting and correcting the conclusions of Walker *et al*. (2006) with respect to coconut, in their paper considering national Priority Setting for Public-Sector Agricultural Research in Mozambique based on National Agricultural Survey Data, which states:

> "In both the actual and the illustrative desirable allocations" [for public sector agricultural research], "several commodities or groups of commodities do not receive any resources. … Coconut could qualify for public-sector research support because it is an important commodity in the lowland coastal agroecologies. But demand is weak and, historically, lethal yellowing, which is wreaking havoc in the sector, has only been controlled in other infected countries by elimination of trees and the subsequent effective enforcement of quarantine procedures. Smallholders in Mozambique are not likely to eliminate trees to combat this devastating disease. A French-assisted project is also working with large growers to propagate disease-resistant or tolerant material. IIAM should maintain a watching brief on coconut."

5.4 In response to these points:

- The consultant questions whether demand is weak. Although coconut may not rank highly as a traded commodity of national importance in purely economic terms, it has considerable local and regional importance as a low input, low maintenance and all-seasonal crop that can be grown on land for which there are few alternative options, and none with a similar nutritional profile. Few would doubt that is also a key component of national diet.
- Productivity, and probably to some extent popularity, of coconut are constrained by an ageing palm population as well as the threat of disease, both of which reflect under-investment in promoting and adopting improved management practices and in publicly-funded research to support these.
- The facts about control of lethal yellowing are wrong: there is in fact little published evidence that LYD "have only been controlled in other infected countries by elimination of trees" and no factual evidence at all that "subsequent effective enforcement of quarantine procedures" is important. Recent observations in Africa have indicated that progress of the disease can indeed be dramatically reduced by prompt elimination of palms at early stage of infection, but large-scale implementation has not yet been attempted so the impact is unknown.
- In other countries, control has usually been achieved by the rapid introduction and exploitation of coconut types that are less susceptible to the disease, and these have often been grown right under or alongside affected palms. Such control measures have only been possible because governments or commodity boards have had the foresight to invest in research that has allowed early identification of disease resistance.
- The French-assisted project ceased operations at least three years ago. Although a small amount of short-term funding has been conserved to screen disease-resistant material for the common good, with limited support from GoM and from one of the large growers whose very future is threatened by the disease, these resources are far from adequate.

5.5. It may be true that smallholders in Mozambique are unlikely, or at least unwilling, to eliminate trees to combat LYD. However, in Mozambique there is a coincidence of interests, unique for coconut cultivation in Africa, between smallholders and an estate sector that is motivated and potentially able to contribute resources to combat the disease in this way, in order to tackle the problem for the common good. The public sector - government, donors, research agencies and their advisers - would do well to recognize and take advantage of this fast-closing window of opportunity, before the disease overwhelms coconut cultivation in central Mozambique and the livelihoods that depend on it.

6. Recommendations

6.1. A national co-ordinator should be appointed to organise, as soon as possible, a small working group in order to generate awareness about the threat of disease and the need for investment to rejuvenate ageing coconut plantings, and to seek a participatory consensus about the future of the industry and ways to move forward. Such a consensus between public (as represented by both government and non-government, community-based organisations) and private sectors is especially important in order to encourage a favourable climate for private sector investment and hence support for long-term research and development for the common good.

6.2. The working group should be prepared to consider economic and social as well as biological constraints. It should have specific objectives, outputs and targets against which a small budget could be provided to facilitate meetings, information dissemination and specialist inputs if required.

6.3. Consider ways to assist implementation of the large-scale cutting down and replanting programmes that were originally planned under the PASCOM project and are currently being partially implemented on a small-scale under GTZ Public-Private partnership funding. New initiatives should incorporate lessons learned under the GTZ project. Initially, this should target high-risk and epidemic areas where there appear to be best prospects for impact.

6.4. Although there are good prospects of demonstrating impact over a five-year period, so far as possible this should be regarded as “kickstarting” a long-term commitment towards control, for which the growers themselves will have to become largely responsible. In order to encourage sustainability, consider supporting activities to enhance production from existing coconut palms, and to enable farmers to produce added value products. Both of these activities show prospects of an economic return within 5 years. There may also be prospects of attracting long-term investment under carbon trading partnerships.

6.5. Given the current social, economic as well as biological realities of facing the estate sector, consider providing support for the participatory land management approaches. These would need to be carefully monitored so that lessons are learnt and management practices modified accordingly. Support could take the form of start-up funding, or direct investment in commercial plant or social welfare facilities, conditional on successful implementation of more participatory and productive working practices.

6.6. Consideration of research, and the capacity to support it, was not part of this consultant’s brief. Nonetheless, certain investments have to be maintained and others started if industry is to survive in the medium to longer term and to avoid returning to the same cycle of coconut disease and senility, not to mention productivity that is too low to compete in the global economy. Initially, priority should be given to the maintenance and screening of valuable germplasm imported from West Africa under PASCOM.

7. Postscript

Since writing this report the consultant has become aware of two other relevant developments.

7.1. Firstly, recent progress in immunological methods for the detection of phytoplasmas is likely to lead to practical techniques for the diagnosis of coconut palms in early, probably pre-symptomatic, stages of disease. Subject to suitably low production costs, this could be used to improve the efficiency of large-scale LYD surveillance and control operations. This is based on the ability to clone a dominant phytoplasma membrane protein gene, *secA*, into a bacterial expression system and to produce anti-*secA* antibodies that can be used in a simple enzyme-linked immunological assay such as a membrane-based lateral flow device. A research group led by Dr Matt Dickinson at the University of Nottingham, UK (see http://www.nottingham.ac.uk/biosciences/plantsci/lookup/lookup_role.php?id=NTI1OTE2&page_var=personal), working with researchers from the UK Central Science Laboratory, from Ghana, and Dr Nigel Harrison in Florida, has amplified part of the *secA* gene from coconut LYD phytoplasmas from Tanzania, Ghana and Mexico. The resultant PCR products have been cloned, sequenced and confirmed to be *secA.* These sequences are currently being cloned into an *E.coli* expression vector, and the expressed protein will then be purified and used to produce anti-*secA* antibodies for LYD phytoplasmas. The antibodies will then be evaluated on samples obtained from Ghana to confirm their ability to detect phytoplasma *in vivo.* It is thought that this work could be extended and practical techniques developed within a 12-18 month timescale for use in Mozambique and elsewhere, subject to availability of further funding, some of which may come from a new UK Biology and Biotechnology Science Research Council scheme operating with the UK Department for International Development.

7.2. Secondly, discussion with colleagues in the NR Group (www.theNRGroup.net) and subsequently the UK International Institute for Environment and Development (IIED; www.iied.org) suggest that there could be commercial interest in investment in coconut replanting in the form ofcarbon trading initiatives to offset carbon emission from industrial sectors. This concept is still in its infancy, but some international carbon trading is already occurring, particularly in the forestry sector. Assistance with a coconut rehabilitation programme might be seen by multinational companies as a good way to combine corporate social responsibility with carbon offsetting. This needs to be explored by government and/or private sectors. Enquiry points are the Edinburgh Centre for Carbon Management (ECCM; http://www.eccm.uk.com/) and a guide recently published by Context plc, A UK consultancy specializing in corporate responsibility (see: http://www.econtext.co.uk/downloads/carbon_offset.pdf).

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