Teak predators destroyed by virus from their own larvae

RIU

Validated RNRRS Output.

A simple, effective and environmentally benign method of reducing teak defoliator moth numbers has been tested successfully in Kerala, India. Attacks by the moth dramatically strip the leaves from these valuable trees, causing poor growth and yield loss, distortion of the wood and loss of income for teak farmers. The new method prevents defoliation, minimizes tree damage and increases growth, productivity and employment opportunities. The system uses a baculovirus, obtained from moth larvae and harmless to humans and other insects, sprayed directly on the moths when they appear on the trees, their arrival monitored by forest workers. A pilot virus production plant is already supplying both commercial and government teak plantations in Kerala and neighbouring states. When fully adopted, the strategy will provide jobs for local people as monitors, larvae collectors, and virus sprayers.

Project Ref: **FRP03:**
Topic: **1. Improving Farmers Livelihoods: Better Crops, Systems & Pest Management**
Lead Organisation: **Forest Research, UK**
Source: **Forestry Research Programme**

Document Contents:

Description

FRP03

Research into Use
NR International
Park House
Bradbourne Lane
Aylesford
Kent
ME20 6SN
UK

Geographical regions included:

India,

Target Audiences for this content:

Forest-dependent poor,

A. Description of the research output(s)

1. Working title of output or cluster of outputs.
In addition, you are free to suggest a shorter more imaginative working title/acronym of 20 words or less.

Use of baculovirus control agents within an integrated management strategy against teak defoliator moth, *Hyblaea puera*, in India

Short title: Integrated Pest Management of teak defoliator moth

2. Name of relevant RNRRS Programme(s) commissioning supporting research and also indicate other funding sources, if applicable.

Forestry Research Programme: Hillside Production System

3. Provide relevant R numbers (and/or programme development/dissemination reference numbers covering supporting research) along with the institutional partners (with individual contact persons (if appropriate)) involved in the project activities. As with the question above, this is primarily to allow for the legacy of the RNRRS to be acknowledged during the RIUP activities.

R6295/ZF0020

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*4. Describe the RNRRS output or cluster of outputs being proposed and when was it produced? **(max. 400 words)**. This requires a clear and concise description of the output(s) and the problem the output(s) aimed to address. Please incorporate and highlight (in bold) key words that would/could be used to select your output when held in a*

database.

The primary goal of the DFID **Hillside System** is to increase the productivity of **plantation forestry on hillsides**. Its purpose is to develop strategies for the efficient management of plantation forestry on sloping lands supporting the livelihoods of local people. The research presented here developed **environmentally benign** methods of reducing populations of **teak defoliator moth**, minimising damage to the trees, increasing growth and productivity and hence employment opportunities and income security for local people.

Using existing data as a starting point, the programme further extended a ***Control Window*** conceptual **model** already used successfully in pest management in the UK. The research comprised inter-related components of which the phase funded by DFID was completed in November 1998.

The programme achieved its main aims to

- improve monitoring of moth populations
- develop improved knowledge on virus **dosage-mortality** relationships
- develop **virus mass production** systems
- assess individual parameters within a Control Window concept
- predict field dosages
- test predicted dosages in the field

This research showed **virus-application** to be a realistic methodology that provides safe and relatively cheap IPM, using spray technology which is both sophisticated and cheap and easy to use by smallholders and plantation owners.

Reductions in moth populations and tree damage were demonstrated. Work by KFRI shows such damage equates to changes in volume amounting to around 3 $m^3 yr^{-1}$ and significant increases in yield and quality of teak. There have been improvements in the formulation since 1998.

Partly driven by the considerable interest from the private teak plantation sector in India, the Indian Department of Biotechnology has funded a pilot virus production plant to supply virus to both commercial and government teak plantations in Kerala and teak-growing neighbouring states.

Once adopted, the full IPM strategy proposed will involve local labour in field monitoring, field collection of larvae (for virus production) and in application of virus in the field. There would also be benefits in training and setting up extension services.

The on-going employment created to manage the pest problem will provide much needed income to sustain poor communities in remote areas of particularly challenging and fragile environments. The coconut oil used as base for the formulated virus product is also produced locally, supporting small scale indigenous industry.

5. What is the type of output(s) being described here?

Please tick one or more of the following options.

Product	Technology	Service	Process or Methodology	Policy	Other Please specify
	X				

6. What is the main commodity (ies) upon which the output(s) focussed? Could this output be applied to other commodities, if so, please comment

Teak (*Tectona grandis*) is the main commodity.

This IPM approach could be applied to other tropical hardwood systems that are subject to attack by forest defoliators.

The teak defoliator moth (*Hyblaea puera*) is also a serious pest of *Avicennia marina*, which is a major component of the highly fragile mangrove ecosystem.

7. What production system(s) does/could the output(s) focus upon?
Please tick one or more of the following options.
Leave blank if not applicable

Semi-Arid	High potential	Hillsides	Forest-Agriculture	Peri-urban	Land water	Tropical moist forest	Cross-cutting
		X					

8. What farming system(s) does the output(s) focus upon?
Please tick one or more of the following options (see Annex B for definitions).
Leave blank if not applicable

Smallholder rainfed humid	Irrigated	Wetland rice based	Smallholder rainfed highland	Smallholder rainfed dry/cold	Dualistic	Coastal artisanal fishing
					X	

*9. How could value be added to the output or additional constraints faced by poor people addressed by clustering this output with research outputs from other sources (RNRRS and non RNRRS)? (**max. 300 words**).*

Please specify what other outputs your output(s) could be clustered. At this point you should make reference to the circulated list of RNRRS outputs for which proformas are currently being prepared.

The Royal Forest Department, Thailand, has carried out research to manage the teak defoliator moth using bacterial and plant-derived pesticides (Sakchoowong, 2002).

However, this work has not extended to a full IPM strategy for the moth. Researchers in Thailand and the local

teak industry are likely to be early adopters of the IPM approach, having already recognised the impacts of the moth on teak growth and yield. Encouragement of teak planting by smallholders is being practised in Thailand (Mittelman, 2000). In particular smallholders are developing small plantations mixed with rows of *Azadirachta indica* (neem) or mixed with fast-growing fruit and other trees, farm boundaries and scattered groups of trees. Thus, participating famiies have between 5 and 3000 trees many interspersed with annual crops. Even in these small-scale situations, the ultimate purpose of the trees includes saleable timber during thinning and at rotation age. Thus incomes per ha from a system of mixed teak, multipurpose tree species and cash crops can yield $10200 after 10 years and $21795 after 20 years, compared with $3720 and $7440 for upland cash crops in the same periods. A loss of growth from defoliation by teak defoliator moth would, therefore, have a significant effect on these projections and this has been recognised in Thailand.

Extending similar approaches to forestry departments and pest management practitioners in Bangladesh, Indonesia and Sri Lanka, the main teak growing countries where moth outbreaks are known to occur, is likely to show similar and significant advantages to local people in each country.

Key parameters are to increase understanding of the large effects of the moth on teak yield and to demonstrate that IPM would enable cost-effective management to be carried out, while also offering prospects for employment of unskilled labour in rural locations where poverty is likely to be highest.

Validation

B. Validation of the research output(s)

*10. **How** were the output(s) validated and **who** validated them?*

*Please provide brief description of method(s) used and consider application, replication, adaptation and/or adoption in the context of any partner organisation and user groups involved. In addressing the "who" component detail which group(s) did the validation e.g. end users, intermediary organisation, government department, aid organisation, private company etc... This section should also be used to detail, if applicable, to which social group, gender, income category the validation was applied and any increases in productivity observed during validation **(max. 500 words)**.*

There has been a range of validations carried out on the programme outputs, reflecting technical evaluations and departmental, State and National Governments as well as end users.

The original DFID programme was assessed by a referee who supported the outcomes and conclusions from the research. She/he concluded that the project made a significant contribution and achieved the majority of the desired outputs. Specific recommendations made by the referee included:

- Further research, through a 1-2 year extension in funding, to refine monitoring techniques, virus production systems and use of field validation trials to confirm and extend the findings from the original research. It was not possible to obtain this funding from DFID, but further work has been done by KFRI using funds from State

and Central Governments.
- Dissemination by articles and specific targeting of audiences (both end user and scientific) in India. Focus on "popular" widely-read magazines has been combined with articles in scientific journals.

The referee was uncertain about future uptake in relation to a pilot scale virus production plant. Fortunately, this has been funded by Department of Biotechnology, India and specific improvements made to production systems.

The Department of Biotechnology (DBT), Government of India through its Taskforce on Biopesticides and Crop Management has strongly supported the work. Arising from the outputs of the DFID programme as well as ongoing work at KFRI, DBT has funded a research project and virus production facility.

"Now, the teak defoliator research team at KFRI has come to a stage where they have standardized HpNPV technology for use in the field, have applied for a patent for the baculovirus product and have already started transferring the technology to the major stakeholder – the State Forest Department. It is with immense pleasure that I recollect the productive association between DBT and KFRI in tackling a major pest problem of this country".

Seema Wahab, Advisor to DBT

The Consultative Group for Forestry Research and Management (CGFRM) is an advisory body constituted by the Council for Science, Technology and Environment for KFRI. It assesses and prioritises the research and development programmes for KFRI. They assessed the teak defoliator programme in 2005 and concluded

"Biological control of teak defoliator pests by HpNPV is an acceptable proposition to the Forest Department. But there is a need to popularize the technology among the department staff".

This endorsement was welcomed by KFRI, which accelerated dissemination of the technology.

Most satisfying are comments received from real end-users in the state sector (Kerala Forest Department) and local smallholders, both in Kerala and in neighbouring States. The shift from chemical insecticides to a method that is harmless to users has been particularly well received.

"it is seen that a huge quantity of insects are lying scattered on the ground and many of them are lying dead, stuck on the leaves itself. Looks as if the Kerala medicine, i.e. HpNPV has performed very well. We thank you for this wonderful medicine".

Letter received from teak farmer who has adopted the IPM system

*11. **Where and when** have the output(s) been validated?*

*Please indicate the places(s) and country(ies), any particular social group targeted and also indicate in which production system and farming system, using the options provided in questions 7 and 8 respectively, above **(max 300 words)**.*

Validation has been concentrated in Kerala State, India reflecting the proximity of the KFRI research team and

the many teak forests with a range of owners in Kerala.

The Hillside production system addresses the Plantation Forestry commodity base. This Dualistic farming system specifically includes large plantation forests, owned either by the state or commercial forest companies and improvements at this level can provide employment for semi-skilled local workers and so support families. In contrast, smallholders with a few teak trees in a small plot will be able to realise cash income from selling harvested wood.

Validation has proceeded as the KFRI team have worked jointly with the Rajiv Gandhi Centre for Biotechnology, Trivandrum to improve monitoring and virus production (this joint work has been funded and validated by DBT). They have also carried out field demonstrations and encouraged uptake (with endorsement from both private owners and Kerala Forestry Department).

Outputs from the programme have been exposed to peer review through a variety of journals, publications and presentations resulting in positive feedback from plantation owners as well as the scientific community. Examples of publications and meetings include:

Pest Management in Tropical Forest Plantations (2002). FORSPA Publication No 30/2002

Sudheendrakumar, V.V. (2002) Current status of microbial control of forest insect pests. In *Proceedings of the ICAR-CABI Workshop on Biopesticide Formulations and Application.* 107-116.

Nair, K.S.S (2005) Pest factor in the intensification of teak cultivation: a global assessment. In Quality Timber Products of Teak from Sustainable Forest Management. *Proceedings of the International Conference on Quality Timber Products of Teak from Sustainable Forest Management*. KFRI, Peechi, Kerala, 445-452.

Sudheendrakumar, V.V., Sajeev, T.V., Varma, R.V., Biji, C.P. and Mahiba Helen, S. (2006) Current status of the use of baculoviruses for management of forest insects pests in India. XII Silvicultural Conference, FRI, Dehra Dun. p. 18.

Current Situation

C. Current situation

12. ***How and by whom*** *are the outputs currently being used? Please give a brief description* ***(max. 250 words****).*

Currently, IPM of teak defoliator moth is mainly through direct intervention by KFRI scientists within the forests owned by Kerala Forest Department. Staff of the Forest Department have been trained in the methodologies and are also disseminating the information about IPM of teak defoliator. Delivery is through employment of staff to monitor the arrival of the moth and direct liaison with KFRI staff who deliver the virus preparation, assess the site characteristics and oversee the spray operation. At this stage, this serves both to manage the moth population and also to reinforce and extend the training already delivered (see question 16).

There has also been demand from an early adopter in Chhattisgarh State who was keen to develop non-chemical management regimes for teak defoliator moth on his 15 hectare teak plantation. This teak farmer approached KFRI directly and has successfully used the virus on outbreaks in both 2005 and 2006. He was trained in the processes of monitoring and spray application by KFRI staff, but carried out the spray operations using his own staff, employed specifically for management of his small teak plantation. He is also enthusiastically pointing out the virtues of the system to others in Chhattisgarh State.

*13. **Where** are the outputs currently being used? As with Question 11 please indicate place(s) and countries where the outputs are being used **(max. 250 words).***

The outputs are being used mainly in Kerala State where, apart from the trials that were set up to establish parameters for virus use, there have been treatments of young teak plantations each year from 2000 to 2004. Further details of the scale of use and specific locations are shown in question 14.

Outside Kerala, the IPM approach and final application of virus has been used successfully by one teak farmer in Chhattisgarh State in 2005 and 2006.

*14. What is the scale of current use? Indicating how quickly use was established and whether usage is still spreading **(max 250 words).***

The DFID programme of research into IPM of teak defoliator concluded in 1998, and since then, a virus production facility was established and completed in 2000. This allowed scale up of virus production and a programme of field applications commenced soon afterwards. The applications in Kerala State have been as follows:

Locations for virus treatment in Kerala State	**Area treated (ha)**
Old Amarambalam/Kalikavu, 2 plots	5
Nellikutha/Vazhikkadavu	8
Erampadam/Nilambur	12
Emangad/Kalikavu	6
Chathanporai/Nilambur	3
Old Amarambalam	5
Total area treated in 2004	34

15 hectares of a small privately owned teak plantation in Chhattisgarh were treated in each of 2005 and 2006. This owner is likely to continue to use the IPM process and is helping dissemination by talking to others about the success of the programme.

*15. In your experience what programmes, platforms, policy, institutional structures exist that have assisted with the promotion and/or adoption of the output(s) proposed here and in terms of capacity strengthening what do you see as the key facts of success? **(max 350 words).***

A key factor in the process of adoption of the outputs from the programme is the desire to reduce chemical

insecticides and to promote an environmentally benign pest management strategy. Kerala State has a positive policy to promote biological control strategies and this is echoed in Kerala Forest Department, which is currently the largest user of the IPM approach.

With an important state-wide early adopter actively employing the outputs and also promoting their use, the extension of use to other users, both smallholder and private sector teak plantation owners is gradually taking place.

Platforms for dissemination of the IPM approach have included a number of meetings, national and international conferences and direct workshops for potential end users. This has resulted in knowledge transfer to the staff of Kerala Forest Department who are, in turn, advocating the approach to private teak plantation owners within Kerala. This is accelerating the uptake of monitoring and has fostered a desire to employ virus control to replace any chemical insecticide regimes. The use of training materials in Malayalam, the local language of Kerala, has helped this process.

There has also been direct interaction between KFRI staff and private owners, notably some of the newer companies dealing with intensive teak monocultures. These companies now employ staff specifically to monitor for early arrival of the moth and are keen to employ the virus for management of the pest threat.

Current Promotion

D. Current promotion/uptake pathways

*16. **Where** is promotion currently taking place? Please indicate for each country specified detail what promotion is taking place, by whom and indicate the scale of current promotion **(max 200 words).***

Promotion has been concentrated in Kerala State.

Workshops

- *Monitoring* (March, 2004) attended by 68 Forest Department Staff, including Range Officers, Foresters, Forest Guards and Field Watchers.
- *Application* (May, 2005) attended by 62 staff, as above.

Training Manuals

- Teak Defoliator and Its Control.
  Part 1 – Detection of teak defoliator outbreaks.
  Part 2 – Application of HpNPV
  Written in Malayalam (local language of Kerala State)
  Distributed to Workshop participants.

Booklets

- HpNPV Technology (jointly published by KFRI and Department of Biotechnology, Government of India in 2005)

Other promotional material

- Posters/papers at national and international conferences.

Film

- "Teak Defoliator Management" film has been distributed to Kerala Forest Department and stakeholders within Kerala and to a Film Festival on Forests and Wildlife in Delhi in 2005.

Media

- Press interest in both local and national newspapers. For example, The Hindu (national newspaper) reported positively on the work in December 2003 (arising from an international conference on teak at KFRI) and in July 2006.

Conference

- Quality timber products of teak from sustainable forest management conference jointly organised by KFRI and International Tropical Timber Organization. Held at Peechi in December 2003 and proceedings published in 2005.

17. What are the current barriers preventing or slowing the adoption of the output(s)? Cover here institutional issues, those relating to policy, marketing, infrastructure, social exclusion etc. ***(max 200 words)****.*

An important barrier to creating demand for the IPM methodology is that the effects of infestation by the moth, namely loss of growth and yield, are not recognised. However, the dramatic defoliation that occurs during mass attack by the moth is easily recognised and there is certainly a desire to manage the problem once this is noted. The key is education to show that early detection and treatment will not only prevent defoliation but also bring benefits in faster growth, greater yield and a reduction in distortion of the tree.

Consequently, commercial teak plantation owners will be most aware of the losses they are suffering and so quickest to realise the potential for increased profit. This will have a beneficial result by increasing local employment of poor people to monitor and carry out routine tasks.

This lack of awareness that defoliation should be controlled is even greater outside India, particularly in Africa where the status of the moth and, therefore, its impact is virtually unreported.

Critically, smallholder teak farmers are unaware of the effects of attacks by the moth. They may not react to defoliation or, worse, may apply insecticides indiscriminately with poor efficacy and increased risks to their health.

18. What changes are needed to remove/reduce these barriers to adoption? This section could be used to identify perceived capacity related issues ***(max 200 words).***

A concerted knowledge transfer campaign targeted specifically at key employers in the teak forest industry should be established to indicate the gains in yield and quality to be achieved by managing the moth.

Encouragement of early adopters in the main teak growing countries (particularly Indonesia, Sri Lanka,

Bangladesh, Thailand, Nigeria and Ghana) so that user 'pull' can replace the current provider 'push'. This should result in increased demand for implementation and increased employment of staff to carry out monitoring, local virus production and field application.

In order to achieve widespread awareness of the challenge presented by teak defoliator moth, local smallholders will need to understand the damage it causes and that the IPM method will be cost-effective for them. The level of general education is an important factor. When dealing with smallholders who grow mainly agricultural crops, combining forestry practice extension with existing agricultural extenstion will be advantageous, particularly if there is trust in the current extension workers and their recommendations.

Technical capacity: the most critical factor would be the setting up of local virus production facilities including skill and quality control infrastructures. The expertise to set this up and provide continuing technical support is already available through KFRI.

19. What lessons have you learnt about the best ways to get the outputs used by the largest number of poor people? ***(max 300 words).***

Even with the relatively high level of education among the poor within Kerala, it is not easy to target them specifically either as direct smallholder growers of teak or as employees of larger teak growers. This would be even more difficult in regions and countries where the poor are less well educated.

One key to providing greater benefits to poor people from the outputs is, therefore, to encourage larger teak growers, as the employers, to recognise the value of controlling the moth and, therefore, that the return on an investment in more staff would be covered by greater yields from the teak crop. This yield gain can be in volume, quality and shorter rotation time or a combination of all three. In the typical locations where teak is grown, the greatest pool of labour will be with the rural poor where any form of employment can be difficult to obtain.

An excellent example is provided by the smallholder teak farmer in Chhattisgarh who has recognised the value both of controlling the moth and of using the baculovirus as an effective, environmentally sound control measure. His enlightened approach has resulted in the employment of 6 labourers per day for 300 working days per year, with a high proportion of this related to monitoring and management of teak defoliator moth. Expansion of such successes would result from further specific targeting and also through word of mouth exchange of information with other users local to the early adopters of the outputs in the region, possibly also through exchange visits. As indicated in questions 9 and 22, smallholders in Thailand would also be potential adopters of the IPM approach.

Impacts On Poverty

E. Impacts on poverty to date

20. Where have impact studies on poverty in relation to this output or cluster of outputs taken place? This should include any formal poverty impact studies (and it is appreciated that these will not be commonplace) and any less formal studies including any poverty mapping-type or monitoring work which allow for some analysis on impact on

poverty to be made. Details of any cost-benefit analyses may also be detailed at this point. Please list studies here.

Formal poverty impact studies have only been carried out recently. The economics of mass production of NPV of teak defoliators using laboratory larvae compared with larvae collected in the field from teak plantations highlighted a marginal difference in cost of Rs. 279 and Rs. 317 respectively for treating 1 hectare of infested forest.

In relation to poverty alleviation, a socio-economic analysis of the entire labour force in the operation run by KFRI has been undertaken. The workers were categorised in relation to the production, monitoring and application segments. Production of the formulated product continues all through the year, while the monitoring and field application segments are seasonal over a 6 month period during the teak growing season. A total of 3234 days of work has been generated annually at Nilambur, Kerala, which is divided as follows:

Segment	Person Days			
	Male		Female	
	Skilled	Unskilled	Skilled	Unskilled
Production	204	-	-	360
Monitoring	-	2400	-	-
Application	-	180	-	90
Total	**204**	**2580**	**0**	**450**

It is significant and typical that the production segment is dominated by female employees who show great aptitude for the work and, in many cases (see below) are the heads of their households and see this employment as vital for family wellbeing. The programme has been shown to promote development that is sustainable, not just ecologically and environmentally, but also institutionally, socially, and economically. It was also found to produce positive livelihood outcomes (e.g., adding to income, health, food etc.). The main impact of the programme is on the labourers (mainly unskilled) involved in the production stage, who are all women.

The HpNPV mass production, spraying and monitoring is an adaptive strategy for all the people involved, who have given up certain other activities (like other unskilled labour work and forest activities such as sand mining) to be part of this highly skilled job. For the majority, it is currently a minor coping strategy because of the small scale of production and provides additional income to supplement other activities. At present it does not substantially alter their livelihood situation but, nevertheless, it has immense potential as a development strategy.

A. SOCIOECONOMIC ASSESSMENT

The socioeconomic assessment related to the HpNPV programme was carried out amongst groups involved in the three main elements of the IPM system, viz., the *Production*, *Monitoring* and *Spraying* groups consisting of 26, 11 and 4 units (*household is the unit of study*) respectively. A direct questionnaire survey was conducted for primary data generation. In summary, the survey indicated that the groups were classified as *moderate poor*. Of the three groups, the production group (basically only women) benefits most by way of a regular source of income.

The descriptive statistics of the target groups indicated an average family size of 5.3**,** the sex ratio (on par with

Kerala State) is 1438 female per 1000 male population. Of the total population of 219 from *41* households, females constituted 46 per cent, males 32 per cent and children 22 per cent. Interestingly, 25 of the households were headed by woman. Key statistics gathered during the survey were:

- Education; the level of education does not indicate a satisfactory figure. A low literacy rate was recorded among the target groups.
- Health; common aliments noted were fever, common cold, headache and diarrhoea. They rely on allopathic medicine for treatment.
- Income; the average household income was estimated as Rs.3838, of which income from wage labour constituted 84%. With the Cooperative Bank the major credit provider, 60% of the target group are indebted.
- Employment; the employment structure depicts a dominance of the primary sector with 38 per cent unskilled labourers, indicative of a backward economy.
- Land occupation and use; the average land holding is 48 cents (1 cent = 0.2 ha). Only 50% of the sample possessed livestock. The major fodder source is the natural forest (82%) and the remaining fodder dependence is from their homeland and stall feed. Dependence on natural resources is determined by the socioeconomic conditions of the target group. Firewood, a major requirement of the target group, is usually gathered from the forest which is an open source for the people. Besides these, the energy for cooking and lighting are kerosene (29%) and electricity (71%)

B. THE COST BENEFIT ANALYSIS OF NPV

There are three stages in the application of NPV - Production, Monitoring and Spraying. The CBA of different stages has been carried out to understand the net benefit of the product. The fixed investment includes the capital investment of different machinery used in the stages of production and for application of the product.

Depreciation of the capital investment is set at 2 per cent per annum. The aggregate and net benefits are Rs. 75000 and Rs. 41360 respectively.

Cost Benefit Analysis of NPV	
Fixed Investment	Rs.1049265
Operating Cost	Rs.1404.46
Labour Cost	Rs.11250
Depreciation	Rs. 20985.3
Benefit	Rs. 75000
Net Benefit per ha	Rs.41360.24

The survey indicated that the product has no social and environmental side effects and thus the social and environmental cost of the product is zero.

Economic, Social and Environmental Cost and Benefit of NPV	
Cost	Benefit

Economic Cost = 33639.76 • *Labour Cost =11250* • *Operating Cost = 1404.46* • *Depreciation = 20985.3*	*Economic Benefit* • *Wages = 11250* • *Output = 75000*
Social Cost = 0	*Social Benefit = 0*
Environmental Cost = 0	*Environmental benefit =* *3 cu m of wood / ha / year*

The direct benefits of *the application, based on prices in Kerala State:*

- Generates 95.1 working days per hectare @ Rs. 118.3 per man-day. Labour cost is an addition to the wider economy; i.e. a positive impact of the product by way of societal welfare (employment and income),
- Zero health hazard for the labourers,
- Pesticide avoidance leading to maintenance of natural enemies of the pest,
- Maintenance of the plantation as a common property resource facilitating community activities such as grazing,
- Increased productivity @ 3 cu m of wood / ha / year. To place this in context, the average yield of teak is shown in the Table below. It can be seen that a loss of 3m^3 per annum is extremely significant, particularly in areas where teak is growing poorly in any event.

TABLE. Mean Annual Increment (MAI) maximum and at 50 years rotation age for different site classes (m^3/ha/ year), from Pandey & Brown (2000).

Country	**Best**		**Average**		**Poor**	
	MAI (max)	MAI (50)	MAI (max)	MAI (50)	MAI (max)	MAI (50)
Côte d'Ivoire	17.6	9.5	12.2	7.5	6.8	4.3
India	12.3	10.0	7.9	5.8	2.7	2.0
Indonesia	21.0	17.6	14.4	13.8	9.6	9.6
Myanmar	17.3	12.0	12.5	8.7	5.9	4.3
Nigeria[a]	23.8	13.3	18.5	9.0	13.1	6.8
Trinidad and Tobago[a]	10.2	6.5	7.5	5.0	5.5	3.9

[a] Yield tables have been prepared based on an inadequate number of sample plots and are provisional.

The indirect benefits of the output.

- Better living conditions can lead to better health workers,
- Increased productivity can reduce the total area under plantation making way for increased area under natural forests,
- Maintenance of ecosystem health.
- Carbon sequestration is increased, thus reducing CO_2 emissions.

21. Based on the evidence in the studies listed above, for each country detail how the poor have benefited from the

application and/or adoption of the output(s) ***(max. 500 words):***

- *What positive impacts on livelihoods have been recorded and over what time period have these impacts been observed? These impacts should be recorded against the capital assets (human, social, natural, physical and, financial) of the livelihoods framework;*
- *For whom i.e. which type of person (gender, poverty group (see glossary for definitions) has there been a positive impact;*
- *Indicate the number of people who have realised a positive impact on their livelihood;*
- *Using whatever appropriate indicator was used detail what was the average percentage increase recorded*

Positive impacts on livelihoods based on the key capital assets and outputs of the IPM Programme are as follows:

Human assets:
It helps to diversify income. For example, within Kerala the income from this activity has been used for school fees.

Physical assets:
Income is used primarily to buy food stocks.

Financial assets:
Marginally increased by being able to borrow further funds, mainly because of a steady source of income. This helps the poor to maintain liquidity.

Natural capital:
The IPM Programme has contributed to the protection of forests by way of creating a consciousness among the groups regarding the pest management programmes, leading to improvements in general ecosystem health. A long term assurance that the programme will continue will encourage the younger generation to become familiar with the whole concept, thereby leading to conservation and protection. The specific effect is that the workers gain access to forest for collection of larvae and become more familiar with forest health issues.

Social capital:
Development of a new group of producers, gradually making them self-sustainable. This would allow them to gain power within the community and increase access to external agencies at local and regional levels; e.g. to KFRI and Kerala Forest Department.

Fifty-one people (27 female and 24 male) have been direct beneficiaries during the pilot scale implementation of the technology within Kerala.

The rate of pay for employment on the programme is on par with the rates normally paid by Kerala Forest Department, i.e. an average of Rs. 118 per day. In that sense there is no increase in average pay, but the more certain level of employment, particularly in the production segment is a positive gain.

By contrast, the small farmer in Chhattisgarh State, although employing staff specifically on the IPM programme, pays only an average of Rs. 30 per day. However, the buying power of this wage is likely to be greater in that

area, although no formal assessment of this has been carried out. In this respect, it is interesting to note that workers from other States tend to migrate to Kerala to fill the lowest paid jobs as local workers gain better paid employment and 'move up the ladder'.

Environmental Impact

H. Environmental impact

24. What are the direct and indirect environmental benefits related to the output(s) and their outcome(s)? ***(max 300 words)***

This could include direct benefits from the application of the technology or policy action with local governments or multinational agencies to create environmentally sound policies or programmes. Any supporting and appropriate evidence can be provided in the form of an annex.

The IPM process that is the key outcome of the programme is environmentally benign in that it uses a baculovirus that occurs naturally in the teak defoliator populations; the original isolate of the virus was discovered by KFRI scientists. This is highly specific and does not affect other non-target species, even in the Lepidoptera, within the ecosystem. The approach is supported strongly by both Kerala State and by the Central Government of India. Apart from being a biorational method of pest control, the virus replaces an intermittent regime of chemical insecticide use against teak defoliator moth. Two insecticides have been used in recent years; endosulfan, an organochlorine, and quinalphos, an organophosphate. Both are highly toxic to a range of organisms, including non-target bees, fish, birds and mammals. Their use is normally highly regulated and, for example, endosulfan has been banned in a number of countries across the world.

Kerala State policy is to reduce chemical insecticide usage. In the light of particular concerns expressed about the use of endosulfan, which has been the subject of a study on impacts on human health in protection of cashews against insect pests, Kerala has banned this insecticide. Aerial application of insecticides, which would be particularly applicable to control of forest pests and has previously been tested against teak defoliator moth in 1965, has also been banned within Kerala.

The IPM approach is, therefore, fully compliant with Government policy.

25. Are there any adverse environmental impacts related to the output(s) and their outcome(s)? ***(max 100 words)***

There are no adverse environmental impacts related to the output and outcome. As explained above, the approach is environmentally sound and offers positive benefits in reducing chemical insecticide usage.

26. Do the outputs increase the capacity of poor people to cope with the effects of climate change, reduce the risks of natural disasters and increase their resilience? ***(max 200 words)***

In relation to climate change, the increase in yield of the teak and use for building and other long-term uses, will lock more carbon and hence reduce CO_2 emissions relative to unprotected teak.

There is a strong market in developed countries for tropical hardwoods, much of which is supplied by unsustainable destruction of primary forests across fragile ecosystems.

Improving the safety and productivity of plantation production of teak will:

- Encourage a market in sustainable building and wood products
- Make uncontrolled felling of primary forests less cost-effective
- Diversify smallholder income
- Contribute to carbon sequestration and could provide carbon credits as a further means of income generation

Avicennia marina is a major component of the fragile mangrove ecosystem and is attacked by teak defoliator moth. This would be a potential further application of the IPM system.

Annex

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