RESEARCH

Impact assessment of forestry technologies for the humid tropics of Mexico

Evaluación de impacto de tecnologías forestales para el trópico húmedo de México

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Abstract

The purpose of this research was to carry out an impact evaluation, in the humid tropics of Mexico, of the forestry projects and technologies generated at the El Tormento Forest Technology Transfer and Research Center. This was achieved through a longitudinal descriptive research, which covered the period from 1961 to 2007; For this, different types of documents and publications were consulted, interviews were conducted with key informants (researchers and producers); Likewise, different bibliometric indicators were calculated to analyze the scientific productivity of the Center; The information collected was systematized in Excel format and the interviews were analyzed with the statistical package Predictive Analytical Software and Solutions (PASS) version 22. It was identified that 49.8% of the documents corresponding to summaries published in reports and conferences, which facilitated the dissemination the results of forestry research; there is a tendency towards individual publication of the authors, rather than the collaborative one. Most of the projects identified were financed by Fundación Produce Campeche A.C., CONAFOR and INIFAP. 19 technologies were identified for different forest species. 35% of the producers stated that they knew INIFAP and, of them, half had applied INIFAP technology.

Keywords: indicators, forest productivity, tropical species

JEL Codes: O33, O22, Q20

Resumen

El objetivo de este trabajo es el de realizar una evaluación de impacto, en el trópico húmedo de México, de los proyectos y tecnologías forestales generados en el Centro de Investigación y Transferencia de Tecnología Forestal El Tormento. Lo anterior se logró mediante una investigación descriptiva longitudinal, que comprendió el período de 1961 a 2007; para ello se consultaron diferentes tipos de documentos y publicaciones, se realizaron entrevistas con informantes clave (investigadores y productores); asimismo, se calcularon diferentes indicadores bibliométricos para analizar la productividad científica del Centro; la información recabada se sistematizó en formato Excel y la entrevistas fueron analizadas con el paquete estadístico Predictive Analytical Software and Solutions (PASS) versión 22. Se identificó que 49.8% de los documentos correspondieron a resúmenes publicados en memorias y congresos, mismos que facilitaron la difusión de los resultados de la investigación foresta; se observó tendencia a la publicación individual de los autores, más que a la colaborativa. Los proyectos identificados en su mayoría fueron financiados por Fundación Produce Campeche A.C., CONAFOR e INIFAP. Se identificaron 19 tecnologías para diferentes especies forestales. El 35% de los productores manifestó conocer al INIFAP y, de ellos, la mitad ha aplicado la tecnología.

Palabras clave: indicadores, productividad forestal, especies tropicales

Códigos JEL: O33, O22, Q20

Introduction

The analysis and evaluation of results and information derived from any scientific or technological research project in general, and particularly in the agricultural and forestry sector, are necessary for both those involved in it (researchers and beneficiaries), as well as for those who must make decisions regarding it (funding sources or institutional authorities), and for the decision-makers themselves (public policy) (Vázquez et al., 2010).

This evaluation may be carried out at two levels: the first related to the producer and their production unit, which implies measuring the changes resulting from the application of technology, production costs, productivity, profitability, sustainability, and competitiveness, as well as the producer's income. The second level involves measuring the changes in society due to the application of technology, in addition to improvements in the well-being of both consumers and producers (Alston et al., 1995).

Likewise, the evaluation of a research project must be conceived as a process of activities; therefore, depending on the period in which the review is conducted, it may be an ex-ante, process, ex-post, or impact evaluation (Bobadilla et al., 1998; Medianero, 1998; Pérez, 1999; Vásquez et al., 2001). The ex-ante evaluation is carried out before the project is approved and examines its relevance, feasibility, and potential effectiveness; the process evaluation is conducted during the project's execution to monitor the progress of objectives or results in order to improve or identify critical points; the ex-post evaluation is conducted when the project has concluded to determine the degree of objective fulfillment and to demonstrate that the changes produced are the result of the planned activities. In turn, impact evaluation investigates permanent changes as well as improvements in the quality of life of the beneficiaries (Aramburú, 2001; Vélez et al., 2013).

In this regard, one of the primary activities of the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), an institution of scientific and technological excellence, is the generation of scientific knowledge and technological innovation in agriculture and forestry in response to the various demands of the sector. This is achieved through the development of research projects in its various experimental fields distributed throughout the country, which address the priorities of agri-industrial chains to contribute to the sustainable rural development of each region.

These projects have occasionally undergone the corresponding evaluations, particularly ex-post and impact evaluations (e.g., Espinoza et al., 2018); however, this aspect of evaluation has not always been fulfilled, which implies a lack of understanding regarding the impact of these projects on science, technological innovation, economic progress in a given entity, the quality of life of its beneficiaries, and the conservation of natural resources.

Among the projects and technologies pending evaluation are those developed at the current Centro de Investigación y Transferencia de Tecnología Forestal (CIyTTF) El Tormento, formerly an INIFAP Experimental Field, which was founded in 1961 with the objective of developing techniques for the management of the forest resources offered by the humid tropical forests of Mexico (Uzcanga et al., 2018). Therefore, the objective of this study is to carry out an impact evaluation, in the humid tropics of Mexico, of the forestry projects and technologies developed at the CIyTTF El Tormento.

Theoretical Development

Impact evaluation: The impact evaluation of scientific or technological research projects must be conducted sometime after their completion; for example, Medianero (1998) recommends that the waiting period to carry out an impact evaluation be five years. On the other hand, Hueso (2007) defines impact as a process that allows understanding the effects of a project or program in relation to the proposed goals and assigned resources. Therefore, this evaluation seeks to validly and reliably verify whether a program or project produced the desired effects on the beneficiaries and whether the cause of such effects is attributable to its implementation. The impacts derived from projects may be:

Scientific: analysis and evaluation of the knowledge resulting from scientific activity, conducted through disciplines known as metrics: bibliometrics, scientometrics, and informetrics (Gorbea, 1994).

Technological: refer to intellectual property, defined as the exclusive proprietary rights granted by the State to individuals or legal entities that carry out inventions, creations, or innovations (Prat, 2009).

Economic: evaluate the effects of research and extension investments on economic, productive, social, and ecological indicators. The main evaluation methods include scoring, cost-benefit analysis, and economic surplus (Vélez et al., 2013).

Social: changes that occur for employees as a result of the use of technological innovations derived from a project, expressed in improvements to the employee's work environment, the sanitary and nutritional quality of the product obtained, the target population's capacities to form or strengthen organizations or support networks, or at the macroeconomic level if the impact provides better opportunities and access to markets for the target population.

Environmental: impacts related to the use of technology aimed at reducing the use of inputs (agrochemicals, energy, natural resources, etc.) and are analyzed based on the quality of environmental components, such as water quality, atmosphere, soil, biodiversity, etc. (Vélez et al., 2013).

CIyTTF El Tormento : The Campo Experimental Forestal El Tormento was established on April 21, 1961, according to the Diario Oficial Tomo CCXLV No. 44, with the objective of developing techniques for the management of forest resources offered by humid tropical forests (Cedeño, 1981). It remained an Experimental Field until 2006, when it became an Experimental Site and functioned as such until the signing of the loan agreement between the Nacional Forestal (CONAFOR), and INIFAP in 2015, to establish Centro de Investigación y Transferencia de Tecnología Forestal “El Tormento”. The research work carried out at this site at the time can be grouped into forest plantations, multiple uses, wood industry, and forest management.

For forest plantations, technological packages were developed for the production of species in nurseries, seed orchards, and clonal banks of species such as Gmelina arborea (melina), Tectona grandis (teak), Swietenia macrophylla (mahogany), Cedrela odorata (cedar), Calophyllum brasiliense (barí), Manilkara zapota (sapodilla), and Cordia dodecandra (ziricote); as well as research in forest health, particularly for the control of Hypsipyla grandella. In the case of multiple uses, exploitation models were developed for Chamaedorea elegans (parlor palm), as well as the implementation of agroforestry and silvopastoral models. For the wood industry, studies were carried out to determine the anatomical and physicomechanical characteristics of tropical wood species, wood properties and uses, as well as the determination of pulp quality indices for paper. In the area of forest management, activities included forest inventories, phenological data of 70 species, implementation of Permanent Silvicultural Research Sites (SPIS), analysis of tree diameter dynamics in secondary vegetation and forests, latex production tables for sapodilla, and training for technical groups (Uzcanga et al., 2018).

Methodology

Study area: The CIyTTF El Tormento is located at kilometer 292 of the Escárcega - Villahermosa highway, 8.5 km from the city of Escárcega, Campeche, México; at latitude 18°16´25” N and longitude 90°43´55” W. The climate in the region is tropical, A(w) 1´g, according to Köppen’s classification as modified by García (1988), with average annual temperatures ranging from 23 to 25°C, maximum temperatures reaching 42°C, and minimums of 4.5°C. The average annual rainfall is 1145 mm, with the highest precipitation occurring from May to October. The predominant soils are rendzina and vertisol (yax´hom and kan´cab), according to the FAO soil classification system.

Research design: The research was descriptive and longitudinal, covering the period from 1961 to 2007, and data collection was carried out using various techniques:

1) Documentary research: Electronic documents of descriptive project files, technological records, forestry publications, and articles were consulted, as well as printed documents and bibliographic collections from the libraries of the Centro de Investigación Regional Sureste del INIFAP, and

a compendium of publications compiled by the authors of this study.

2) Interviews with key informants: Interviews were conducted with active and retired researchers from the forestry area of INIFAP, as well as with producers who benefited from the technology. For this, targeted sampling was carried out in communities involved in any of the projects.

3) Calculation of bibliometric indicators for the analysis of scientific productivity (Machado and Hernández, 2015: pp. 339-340), applying the following indices:

Productivity index, calculated using the natural logarithm of the total number of original documents: IP= log (Td)

Where:

IP= Productivity index

Td= Total number of original documents included in the sample

Associativity index (IA): This indicator was calculated to identify group formation according to productivity. It measures the average number of authors per document within the set of documents under analysis, classifying them as: a) Large (10 or more publications), b) Medium (from two to nine publications), and c) Small (a single publication).

Transiency index: This is expressed as the percentage of transient authors within the analyzed sample. A transient author (AT) is one whose name appears only once in the bibliographic source indexes.

IT= (AT/Ta)* 100 %

Where:

IT= Transiency index

AT= Transient author

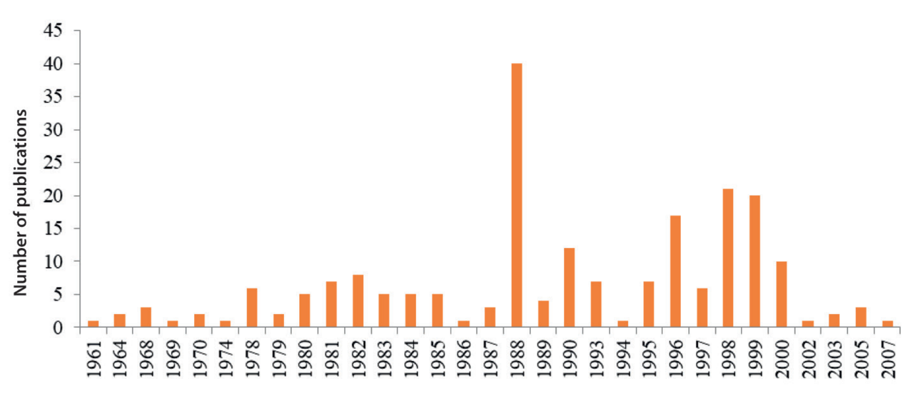
Ta= Total number of authors identified in the sample

Systematization of information: The documentary information was systematized in Excel format, arranged chronologically, and classified by research program and responsible researcher. The technologies were classified by thematic focus, and their benefits were identified. The interviews, both with researchers and producers, were tabulated and entered into an Excel format and analyzed using the Predictive Analytical Software and Solutions (PASS) version 22 (IBM, 2015).

Discussion or argumentation of results

Documentary research and bibliometric indicators :A total of 209 forestry publications from 1961 to 2007 were compiled and classified as follows: 27 journal articles, 15 bulletins, 6 flyers, 17 brochures, 12 technical reports, 1 book, 6 manuals, 1 special publication, 104 compilations and proceedings, as well as 20 theses. In this regard, INIFAP stands out as one of the leading institutions for its contributions to technology transfer, reflected in field guides, brochures, and pamphlets containing practical application information (CONAFOR, 2014). Likewise, it was observed that 1988 marked the period of highest scientific output, with a total of 47 contributions (Figure 1).

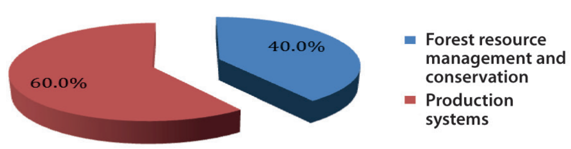
Figure 1. Number of publications analyzed 1961-2007



Out of a total of 92 identified authors, 7.6% were classified as large, 33.7% as medium, and 58.7% as small. Authors in the large category published 10 or more documents, among whom Castillo V., J.C., Gómez T., J., Hernández G., G., Jiménez C., J.M., López T., J.L., Sánchez M., A., and Sarmiento, M. stand out. Overall, a productivity index of 2.3 publications per author was estimated. The associativity index was 0.7, suggesting a stronger tendency toward individual publication rather than collaboration. This trend was also confirmed by the fact that 52.6% of the analyzed documents were published by a single author.

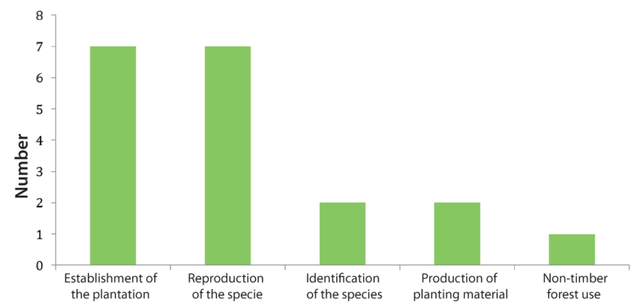
Regarding the projects in operation from 1996 to 2009 linked to the Campo Experimental El Tormento, 10 projects were identified, most of which (80%) were funded by Fundación Produce Campeche A.C., 10% by CONAFOR, and 10% by fiscal funds from INIFAP. Of these, 60% were developed within the production systems program, addressing topics such as forest plantations, genetic resources, the use and exploitation of forest resources, and multiple use. The remaining 40% were classified under the forest resource management and conservation program, dealing with topics related to silviculture and forest planning, commercial plantations, characteristics, and management of forest resources (Figure 2).

Figure 2. Classification of projects by research program



Most of the projects, 70%, were successfully completed, lasted an average of 48.3 months, and were oriented toward the research of various sistemas producto, such as: 40% other forest species, 30% *S. macrophylla*, 20% tropical timber species, and 10% other forest species. Additionally, 19 technologies were identified (Annex 1), among which the most notable topics were the establishment of plantations of *G. arbórea, S. macrophylla*, and *C. odorata*. Other aspects included the reproduction of the species *S. macrophylla, G.arbórea, Delonix regia* (framboyán), *Leuceana sp* (huaxin), *Enterolobium cyclocarpum* (pich), *Piscidia piscipula* (jabín), *Lysilomalatisiliquum* (tzalam), and *Bursera simaruba* (chaká) (Figure 3).

Figure 3. Classification of forestry technologies generated in El Tormento by topic



The development of technology for the control of *H. grandella* in *G. melina*, whose distribution spans tropical zones in México, Central America, and South America—with the exception of Chile (Whitmore, 1978)—was important for México, as this species was introduced in 1971 for the first time at the Campo Experimental El Tormento, from seeds originating in India, plantations in Sierra Leone, Nigeria, and South Africa, and from commercial suppliers in the Netherlands. That same year, four plantations were established to assess its adaptation and behavior. By the third year, they showed fructification, giving rise to a series of research studies on the following topics: species trials, technology, seeds, propagation, plantation establishment, and genetic improvement (Patiño, 1982).

Regarding *S. macrophylla*, in 1990 a seed orchard was established with 25 selected clones originating from the Escárcega, Campeche region, with ten repetitions of each clone, on land belonging to the Campo Experimental El Tormento. Later, in 1996, provenance and progeny trials with *S. macrophylla* and *C. odorata*, established in 1988, were reported, from which genetic parameters were obtained for 36 progenies of both species (Patiño, 1997). Likewise, the review identified that similar studies were carried out on the established orchards of *S. macrophylla* and *C. odorata* in other experimental fields of INIFAP, in order to quantify genetic diversity and relate it to population characteristics, as well as to better understand the reproductive biology of the former species and the biological agents involved, flowering phenology, pollination type, pollinating agent, presence or absence of incompatibility systems, and to determine the fertilization systems and genetic flow occurring among populations and individuals of the species. However, in recent years, the exploitation of these tropical species has shown a downward trend in harvested volumes. In the state of Campeche alone, production decreased from 6,845 cubic meters of roundwood in 1990 to 2,783 in 2012 (SEMARNAT, 2013). Other studies carried out by INIFAP in the field of agroforestry involved collaboration with institutions such as the Centro Internacional de Investigación en Agroforestería (ICRAF), Universidad Autónoma de Yucatán (UADY), El Colegio de la Frontera Sur (ECOSUR), Universidad Autónoma de Quintana Roo, Universidad Autónoma de Chapingo, University of Iowa, United States, and the Ford and Rockefeller Foundations, which funded several projects (Navarro, 1999). These studies aimed to characterize the agroforestry systems of the Yucatán Peninsula and Chiapas, to offer farmers a viable alternative to subsistence. In this regard, studies were carried out to determine farmers' species preferences and to prioritize alternatives, with *S. macrophylla* and *C. odorata* standing out for their high value and interest, which is why they were included in agroforestry processes in the region (Patiño, 1997).

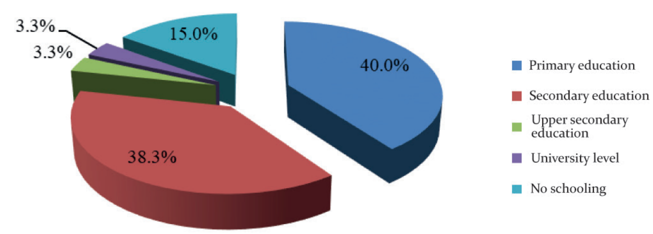
Among the agroforestry timber plantation systems, CONAFOR (2014) refers to the Taungya system in a study on agroforestry systems in México. This system was first used in 1962 at the Campo Experimental El Tormento to establish the first experiment on a four-hectare site with *S. macrophylla, C. odorata*, and corn (Mas and Borja, 1974).

Regarding the impacts of the technologies generated at El Tormento, the current production of *G. melina* is destined for plywood panels, flooring, paneling, and various furniture pieces demanded by the hotel industry. Meanwhile, melina plantations in the state of Campeche, established since 1998, cover 2,000 ha and are mainly located in the Entre Hermanos property, in the municipality of El Carmen, while the industry is located in the municipality of Escárcega, Campeche (CONAFOR, 2013).

Like *G. melina*, the area planted with *T. grandis* has also gradually expanded. Agropecuaria Santa Genoveva S.A. P.I. de C.V. planted approximately 12,374 ha of this species from 2002 to 2014, with a projected annual growth of 1,200 ha, aiming to reach about 20 million trees to be harvested in approximately 18 years, positioning it as the leading teak producer in México (Martínez, 2009).

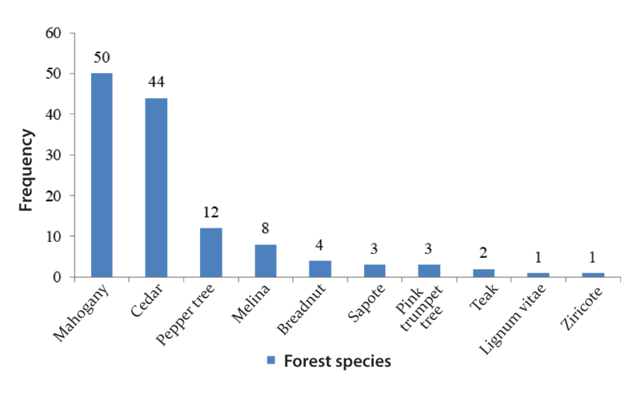
Interviews with key informants: Regarding the beneficiaries of the technologies generated, 66.6% of interviews with forest resource users were conducted in ejidos of the municipality of Calakmul (Nueva Vida, Valentín Gómez Farías, Álvaro Obregón, Heriberto Jara, 20 de Noviembre, El Refugio) and 33.3% in ejidos of the municipality of Escárcega (Haro, Km. 36, and Libertad), for a total of 60 interviews. Most of these producers (40%) had completed primary education, 38.3% had completed secondary education, 15% reported no schooling, 3.3% had completed high school, and 3.3% had a university degree. The estimated average age was 58 years, with 16.6 years of experience in forestry activities (Figure 4).

Figure 4. Education level of forestry producers in the municipalities of Calakmul and Escárcega, Campeche



Regarding the number of hectares established, an average of 5.03 ha per producer was estimated, with plantations approximately 15 years old, and an average density of 608 trees per hectare, where S. macrophylla (39.1%) and C. odorata (34.4%) stood out once again (Figure 5).

Figure 5. Main forest species identified

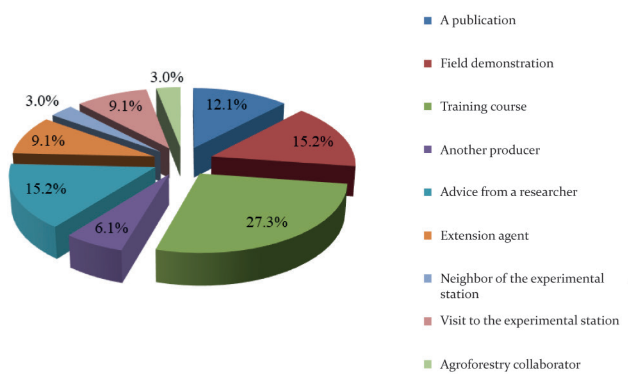


Source: Own elaboration based on research results

Although most of the producers interviewed

(65%) stated that they did not know which institution developed the forestry technology they use, 35% indicated that the technology they use was developed by INIFAP and that they became aware of the institution's work through a training course, a demonstration day, a publication, or technical assistance. The following topics stood out: establishment of agroforestry systems (17.6% of those interviewed), forestry species (29.4%), agricultural species (17.6%), fruit trees (23.5%), planting methods (5.9%), and beekeeping management (5.9%) (Figure 6).

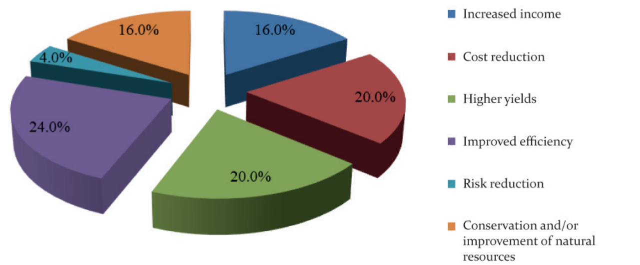
Figure 6. Means by which producers became familiar with INIFAP



The process of technology dissemination is slow, particularly in the forestry sector, due to the time required to evaluate forestry systems. To accelerate dissemination and acceptance, long-term technical assistance is needed. Additionally, the involvement of local individuals, such as technicians, is essential for success and for reducing dissemination costs, as well as for developing local capacities and human resources so that dissemination goes beyond individual projects (CONAFOR, 2014). Nevertheless, the producers stated that the information provided was useful for applying technical criteria, pruning in forestry and citrus crops, soil diagnostics and pest management, crop establishment and planting methods, as well as alternative feeding for bees. Likewise, they reported having applied the technological recommendations at least once, on an average area of 2.5 ha.

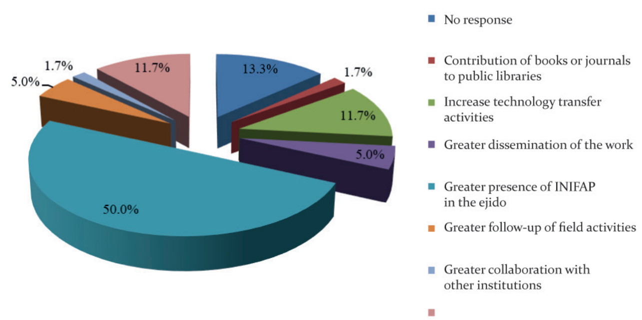
Among the factors limiting the adoption of available technology are the deficient dissemination mechanisms of institutions and the lack of continuity or follow-up in community activities. In general, producers' perception of the benefits of the generated technology highlights improvements in efficiency, cost reduction, and higher yields (Figure 7).

Figure 7. Producers' perception of the benefits of using technology



Finally, some strategies were identified to increase the adoption of technologies generated by INIFAP, among which stand out that dissemination activities and the active presence of researchers in the communities, as well as community involvement, are indispensable for the technology transfer process (Figure 8).

Figure 8. Strategies identified to increase technology adoption



Conclusions

Forty-nine-point eight percent (49.8%) of the analyzed documents corresponded mainly to abstracts published in conference proceedings, and it was observed that this type of event facilitated the dissemination of forestry research results, albeit at a technical level. The trend of the analyzed contributions indicates the authors' preference for individual rather than collaborative publication, as 52.6% of the documents were published by a single author.

Between 1996 and 2009, a total of 10 projects were identified, mostly funded by Fundación Produce Campeche A.C., CONAFOR, and by fiscal funds from INIFAP. Most of these projects focused on topics related to forest plantations, genetic resources, use and exploitation, multiple use, as well as silviculture and forest management, commercial plantations, characteristics, and forest resource management.

Nineteen forestry technologies were identified addressing species such as *C. odorata, S. macrophylla, G. sepium, C. elegans, D. regia, Leucaena sp., E. cyclocarpum, P. piscipula, L. latisiliquum*, and *B. simaruba,* aswell as technologies generated for orchids and agroforestry systems.

Thirty-five percent (35%) of the producers interviewed stated that they were familiar with INIFAP, and of this proportion, just over half had applied technical recommendations at least once, mainly regarding the establishment of forest plantations such as Cedar and Mahogany, as well as crops.

Community presence and work are vital for technology transfer and adoption.

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Appendix 1. List of forestry technologies generated at El Tormento from 1998 to 2009

Technology	Species	Topic	Benefits
		1998	
Fatty acids in Mahogany seed, a limiting factor for its conservation	*S. macrophylla*	Species reproduction	Seed conservation for up to one year in a cold chamber without losing viability, quality, or vigor
Mahogany plant production in nursery	*S. macrophylla*	Production of material for plantations	Production of plants with progenies of good quality
Proposal of signal grass combined with Melina and Mahogany	*G. arbórea* y *S. macrophylla*	Plantation establishment	Integrated pasture management with forestry species as live fences
Melina forest plantations for cellulose production	*G. arbórea*	Plantation establishment	Greater growth compared to other species; pulp has excellent properties for paper production
Melina seed germination	*G. arbórea*	Species reproduction	Germination percentages higher than 90%
Red cedar plantations for sawn timber production	*C. odorata*	Plantation establishment	Wood of this species has various uses: boards, veneer for plywood, furniture, turned articles, cigar boxes, crafts, etc.
Treatments to break dormancy in forest seeds	*D. regia*, *Leucaena* sp, *E. cyclocarpum*, *P. piscipula*, *L. latisiliquum* y *B. simaruba*	Species reproduction	Timely seed germination through hot water scarification to promote germination
Use of organic compost in cedar plant production	*C. odorata*	Production of material for plantations	Improves the physical and chemical properties of the substrate, besides being low cost. Plants showed over 40% superior growth, stem vigor, and greater coverage compared to conventional substrate
		1999	
Spacings with thinning regimes for sawn timber production of *Swietenia macrophylla* (mahogany)	*S. macrophylla*	Plantation establishment	Greater wood production
Quality seed of *Swietenia macrophylla* King (mahogany)	*S. macrophylla*	Species reproduction	Plantation quality control through selection of trees from which seed is collected
Collection, storage, and handling of tropical forest seeds	*C. odorata* y *S. macrophylla*	Species reproduction	Characteristics specific to each species for seed collection: tree height, fruit size, fruit type, dispersal form
Quality seed of *Cedrela Odorata* (Red cedar)	*C. odorata*	Species reproduction	Specifications to guarantee greater genetic viability
Location, identification, and establishment of wild orchids of the State of Campeche	Orquídeas	Species identification	Information for silvicultural planning of ecosystem management and utilization of wild species
Use of Chamaedorea elegans leaf	*C. elegans*	Non-timber forest use	Species valued in national and international markets as floral decoration
Technologies for clearing, chopping, and sowing	Sistemas agroforestales	Plantation establishment	Alternative for sustainable management of cultivation areas to reduce slash-and-burn practices
Management and establishment of live fences	*G. sepium* y *B. simaruba*	Plantation establishment	Provides shade for livestock, post rehabilitation for fences, forage, extraction of energy products such as firewood or charcoal, windbreak, helps reduce extraction of posts from the forest
		2009	
Collection and handling of *Cedrella ordorata L.* (Red cedar)	*C. odorata*	Species reproduction	Selection of seed with better genetic quality for commercialization, as well as to promote and conserve in situ and ex situ the genetic resource of the species