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Luz Del Carmen Lagunes-Espinoza
Colegio de Postraduados

César Jesús Vazquez-Navarrete
Colegio de Postraduados

Joaquín Alberto Rincón-Ramirez
Colegio de Postraduados

Kathleen Halvorsen
Michigan Technological University, kehalvor@mtu.edu

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Coordonnateurs : Laurène Feintrenie, Cesar J. Vázquez Navarrete, Luz del Carmen Lagunes Espinoza

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Oil palm crop: state and gaps of research and technological development at global scale, Latin America and Mexico

Luz del Carmen Lagunes-Espinoza[1] ⬩, César Jesús Vazquez-Navarrete[1,*] ⬩,
Joaquín Alberto Rincón-Ramirez[1,*] ⬩ and Kathleen E. Halvorsen[2] ⬩

[1] Colegio de Postraduados, Campus Tabasco, Periferico Carlos A. Molina s/n, H. Cárdenas, Tabasco 86500, Mexico
[2] AOB, Social Sciences MTU, 1400 Townsend Drive, Houghton, Michigan 49931, USA

Abstract – Oil palm plantations face important challenges in terms of balancing agricultural productivity and environmental sustainability. This research synthesis aims to answer key questions regarding the state and knowledge gaps of oil palm (OP) research and technological development (R&D) at a global scale, in Latin America and in Mexico, using all Web of Science® databases and agriculture categories and time spans between 1960 and 2018. Three thousand nine hundred and forty-eight publications were analysed. The research themes started with the generation of agronomic knowledge in 1960. Since 1963, studies in Latin America have focused on yield improvement; since 2010, topics related to agroecology, product quality, health issues, biodiversity, conservation impacts, and biofuel uses have been widely integrated, although some relevant themes are lacking. In addition, considering the high domestic demand for crude palm oil and great available natural resources, few Mexican institutions have participated in publications registered in Web of Science (WOS) on this topic. This research proposes a quick exploratory and reliable instrument for evaluating the agronomic interest of any agricultural production system.

Keywords: research synthesis / evidence-based decision making / R&D

Résumé – Le palmier à huile : état des plantations et défis de la recherche et du développement technologique à l'échelle mondiale, en Amérique latine et au Mexique. Les plantations de palmier à huile sont confrontées à des défis importants en termes d'équilibre entre productivité agricole et durabilité environnementale. Cette synthèse a pour objectif de répondre aux principales questions relatives à la recherche et au développement technologique (R&D) que pose la culture du palmier à huile à l'échelle mondiale, en Amérique latine et au Mexique, en utilisant les bases de données du Web of Science® sur l'agriculture entre 1960 et 2018. Trois mille neuf cent quarante-huit publications ont été analysées. Dans les années 1960, les recherches ont commencé sur des thématiques agronomiques. En Amérique latine, à partir de 1963, les études ont porté sur l'amélioration des rendements. Depuis 2010, les thèmes liés à l'agroécologie, à la qualité des produits, aux problèmes sanitaires, aux biocarburants, et aux impacts sur la biodiversité et l'environnement ont été largement intégrés. Mais certains thèmes importants sont absents. De plus, il apparaît que peu d'institutions mexicaines participent aux publications enregistrées dans le Web of Science sur le palmier, alors qu'il y a une forte demande intérieure pour l'huile de palme et de grandes ressources naturelles disponibles. Notre démarche propose un instrument d'exploration rapide et fiable pour évaluer les thèmes d'intérêt agronomique de tout système de production agricole.

Mots clés : recherche de synthèse / prise de décision basée sur des preuves / R&D

*Corresponding authors: jrincon@colpos.mx; vcesar@colpos.mx

1 Introduction

The global consumption of crude palm oil (CPO) has increased based on the high population growth rates since the 1960s; it surpassed that of soybean oil in 2007 and became the global dominant vegetable oil. CPO demand is expected to increase by different driving forces, *e.g.*, food consumption patterns, energy policies, and improved quality of life. A consensus has been reached that this demand can be met by improving yields, increasing sustainable production practices, and expanding plantations that prevent the conversion of high conservation value areas. Scientific knowledge plays a fundamental role in addressing this global challenge by improving our understanding of interactions between oil palm (OP) and surrounding landscapes and developing technology and better practices for several different locations (Hoffmann *et al.*, 2017; Murphy, 2014).

OP expansion occurs in humid tropical regions in Asia, Africa, and America; more than 50% of the available and suitable area could be located in South America, Central America, and Mexico (Furumo and Aide, 2017).

Mexican domestic consumption of palm oil was 650 thousand tons in 2018. Although 80% was supplied from imports, domestic cropped area increased over the last 20 years from 10 000 to 77 000 hectares. Mexico has a potential of 8.9 million hectares for OP production, and most could be established on grassland (SAGARPA, 2017; SIAP, 2019). This potential expansion requires strategic information based on scientific knowledge to achieve sustainable production. OP expansion should develop successfully in areas where scientific knowledge is available to overcome most of the limiting production factors and meet environmental criteria, food chain accessibility, and local development demands.

This study aims to identify the relationship between the historical production of oil palm and the spatial dynamics of development and knowledge production. Some questions have arisen from OP expansion at a global scale, specifically in Latin America and Mexico: *i.e.*, a) what countries are generating research and development (R&D) on this crop, b) what topics are being studied, c) how are these topics changing, d) what institutions are carrying out this R&D, and e) where does Mexico fit in comparison to Latin American countries and other producing countries. A review of scientific publications was carried out to respond to these core questions and was used to analyse the knowledge created in this specific research area (Pare *et al.*, 2015); a historical and geographical approach was used to link knowledge creation to agricultural development dynamics. A comprehensive understanding of this baseline information by considering different disciplines, such as agronomical, processing, social and environmental disciplines, is a key starting point (Padfield *et al.*, 2019; Woittiez *et al.*, 2017).

2 Methodology

To achieve our research goal, we reviewed the existing literature from different contexts (Cooper *et al.*, 2009; Hood and Wilson, 2001; Pare *et al.*, 2015; Wyborn *et al.*, 2018) and developed an approach that included 9 phases.

1. Search strategy: this search was performed in Web of Science (WoS), and all databases were consulted. In WoS, three keywords related to OP, "oil palm" OR "*Elaeis guineensis*" OR "African palm", were selected by using the TOPIC field. OP-related publications were selected between 1960 and 2017.
2. Revision of the preliminary dataset: a revision of the preliminary results by identifying the main research categories of OP knowledge using WoS analyzing tools.
3. Criteria selection: Three criteria to select publications were used: i) papers that were classified as *Agriculture* according to the WoS classification system; ii) papers that had an abstract or general description; and iii) papers that had basic information related to the main research topics.
4. Main research topics: Based on our research objectives, two sets of keywords related to core performance indicators classified into three category levels were proposed (Tab. 1).
5. Algorithm selection: Considering the main research topics, publications were classified by using the following decision tree (Fig. 1). For publications with several research topics that were classified based on their relation to a yield-oriented indicator of OP, the classification was carried out in an Excel program.
6. Analysis unit: A dataset of publications related to OP was generated. A total of 863 publications were not considered in the analysis since they were duplicated and had missing information. The final dataset based on agricultural research areas consisted of 3948 bibliography references and seven tag fields for analysis: title, abstract, authors, keywords, country, author information (*e.g.*, institution, country), and year of publication.
7. Exploratory analysis: The analysis of OP knowledge was exploratory, and descriptive statistics were used to analyze topics and indicators of the agronomic management of OP, and the results were summarized in figures. Series analyses were also performed to identify changes and tendencies in the different topics during the studied period. Some associations were tested to shed light on the interactions between outcomes and OP knowledge results.
8. Results outline: The results were organized based on the research questions.
9. Recommendations for decision-making: A "storyline" was provided for decision-makers to clarify the problems and opportunities identified based on OP agronomic practices designed to improve yield and other important topics.
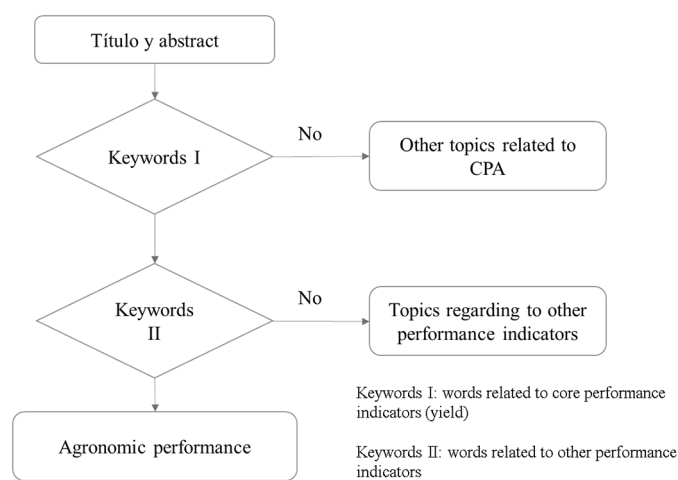
3 Results

3.1 Description of the dataset

In total, 9886 publications were identified in the preliminary revision phase, of which 2201 were patents. Considering the research area classification system of WoS, 4731 publications were identified in agriculture, 3296 were identified in plant science, 432 were identified in biodiversity and conservation and 651 were identified in environmental science and ecology. Between categories, 2439 publications were repeated. In 1960, a total of 2 publications were

Fig. 2. Oil Palm Crop acreage and number of publications on oil palm crop by country in 2017 (with a zoom on Mexico).
Fig. 2. *Surfaces cultivées en palmier à huile et nombre de publications sur cette culture par pays en 2017 (avec un zoom sur le Mexique).*
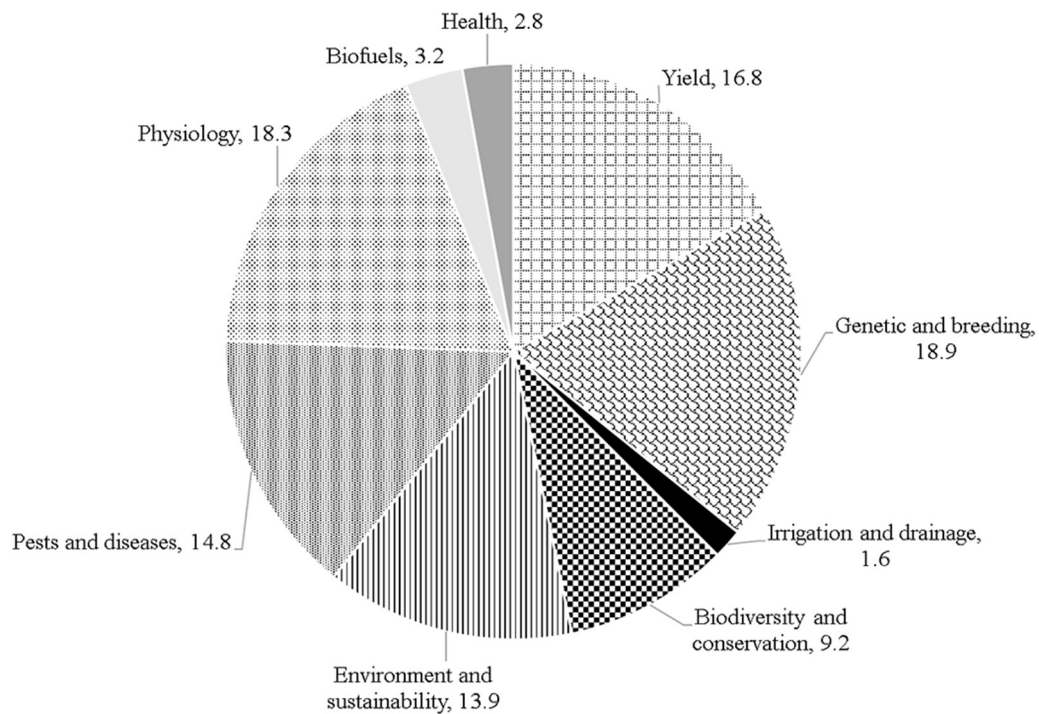
Fig. 3. Frequency (%) of main research themes on OP during 1960–2017.
Fig. 3. *Fréquence (%) des principaux thèmes de recherche sur le palmier à huile entre 1960 et 2017.*
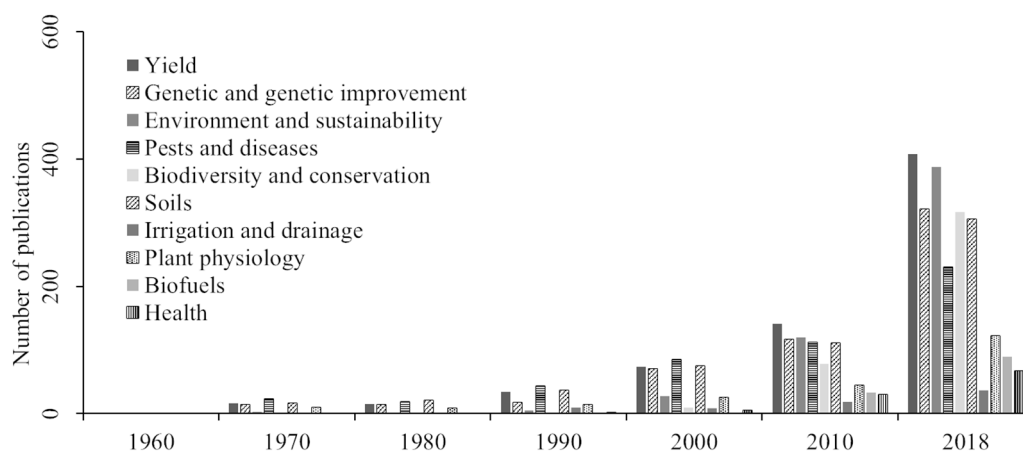
Fig. 4. Evolution of research themes on OP during 1960–2018.
Fig. 4. *Évolution des thèmes de recherche sur le palmier à huile entre 1960 et 2018.*
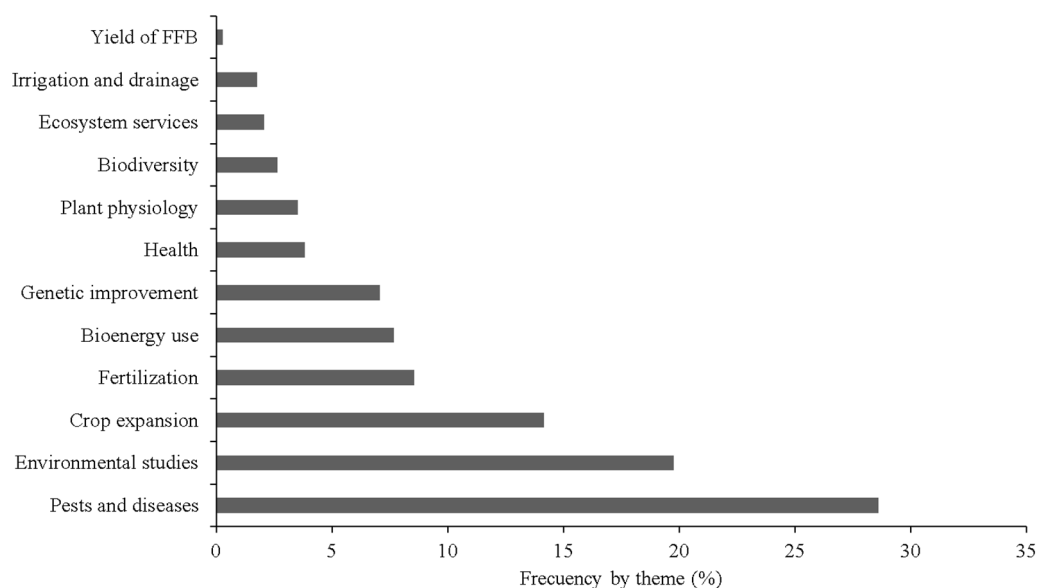
Fig. 5. Frequency (%) of the main research themes on OP in Latin America during 1960–2018.
Fig. 5. *Fréquence (%) des principaux thèmes de recherche sur le palmier à huile en Amérique latine entre 1960 et 2018.*

(Murugesan *et al.*, 2017; Rivera Mendez *et al.*, 2012), the effect of irrigation and drainage (1.7%), yield of FFB (0.2%) (Contreras *et al.*, 2012; De Farias Neto *et al.*, 2013), the use of OP as a bioenergy feedstock (7.6%) (Aristizabal *et al.*, 2016; Cardoso *et al.*, 2017), and the impacts on biodiversity (2.6%) (Alonso-Rodriguez *et al.*, 2017; Knowlton *et al.*, 2017) and ecosystem services (2.0%) (Frazão *et al.*, 2013; Lavelle *et al.*, 2014). Other studies also focused on the impact of palm oil on human consumption by characterizing oil products and health conditions (3.8%) (Irias-Mata *et al.*, 2017, Sandoval-Garcia *et al.*, 2016) (Fig. 5).

3.5 What is the OP R&D baseline in Mexico?

The introduction of OP in Mexico started in 1980 and recently accounted for 90 118 ha distributed in four states: Campeche, Chiapas, Tabasco, and Veracruz (SIAP, 2019)

(Fig. 2). Most of the production is used for food, and 32% is associated with other industrial uses (FAO, 2018). The number of publications found in the WoS databases is limited (10 papers), and the research subjects are disconnected. Publications dealing with the social impacts of OPs (Castellanos-Navarrete and Jansen, 2018), the effect of the production and expansion of OPs on land-use change and biodiversity (Aguilar-Gallegos *et al.*, 2015; Castellanos-Navarrete and Jansen, 2015; Furumo and Aide, 2017; Lin *et al.*, 2012), and the use of environmentally friendly and less impacting practices in Chiapas have been published (Castellanos-Navarrete and Jansen, 2018). One article on methods of using palm oil as a biofuel (Sandoval-Garcia *et al.*, 2016) and two papers on pests and diseases, *Raoiella indica* Hirst (Otero-Colina *et al.*, 2016) and *Calyptocephala gerstaeckeri* Boheman (Cordova-Ballona and Sanchez-Soto, 2008), were published.

3.6 Which institutions have carried out R&D on OP in Mexico?

Mexican institutions found in the WoS that have performed research on OP include the *Instituto Nacional de Investigaciones Forestales, Agricolas and Pecuarias* (INIFAP) and *Colegio de Postgraduados*, Campus Tabasco. Other institutions that have carried out social and environmental research on OP in Mexico include the *Universidad Autonoma Chapingo*, *Universidad Autonoma de Chiapas*, *el Colegio de la Frontera Sur* and *Universidad Juarez Autonoma de Tabasco.* Most of these institutions are publicly funded and the performed OP research was based on their location.

4 Discussion

The global R&D of OP is associated with different scientific knowledge platforms, and such platforms allow researchers to determine the current state of a particular research subject at any temporal and spatial scale, which was confirmed in this study and in other research (Bartol *et al.*, 2014; Scherm *et al.*, 2014; Wyborn *et al.*, 2018).

This study highlighted the relationship between the number of publications/year and the expansion of oil palm plantations in countries such as Malaysia, Indonesia, Colombia, Brazil, and Mexico, as brought to light by Abrizah (2012).

As argued by other scholars, such as Castellanos-Navarrete and Jansen (2017), this study also showed a change in the patterns in thematic research areas, based on issues raised regarding oil palm development and its responsible consumption, such as the certification and creation of the Roundtable on Sustainable Palm Oil (RSPO), production of biofuel, etc.

Based on the analysis of previous research, this study also provided practical knowledge to estimate research performance indicators, such as the number of publications per country, per scientific staff, and per core research subject. Future studies could implement this strategic knowledge to foster a decision-making process based on evidence.

5 Conclusions

The analysis of global and Latin American scientific knowledge on the R&D of OP and the comparison with the knowledge from Mexico revealed a R&D gap on agronomic and socioecological topics and very few scientific products generated (number of articles and patents), which might be explained by the few research institutions involved in these research areas in Mexico. These results are inconsistent with those concerning leading OP countries. Although several research areas were identified and are similar to the ones found in other studies (Abrizah, 2012), Mexican R&D is focused on three areas. Thus, it is recommended to foster agronomy, technological innovation, and socioecological issues. To encourage OP R&D in Mexico, effective public policies are required to incentivize cooperation between key stakeholders, *i.e.*, producers, industry and retailers, to achieve sustainable production and improve the well-being across the food supply chain.

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