Renewable and Sustainable Energy Reviews 76 (2017) 857–864

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Decreasing desired opportunity for energy supply of a globally acclaimed biofuel crop in a changing climate

Junhua Hu

CAS Key Laboratory of Mountain Ecological Restoration and Bioresource Utilization & Ecological Restoration and Biodiversity Conservation Key Laboratory of Sichuan Province, Chengdu Institute of Biology, Chinese Academy of Sciences, No. 9 Section 4, Renmin Nan Road, Chengdu 610041, China

ARTICLE INFO

Keywords:
Climate change
Ecological niche models
Energy supply
Jatropha curcas L.
Cultivation
Sustainability

ABSTRACT

Under the pressure of growing populations and climate change globally, biofuel crops have motivated accelerating interest in the production of renewable bioenergy to provide a substantial proportion of the future energy supply. Both habitat suitability for cultivation and potential aggravating environmental problems from biofuel crops attract concerns worldwide. *Jatropha curcas* L. (Jatropha) is acclaimed as a magical biofuel crop with high potential to replace fossil fuels sustainably, as well as a multitude of environmental benefits. However, Jatropha is categorized as an invasive plant with a massive investment in new cultivations on a global scale but without a profound ecological knowledge. Given the ambitious policy target in production, it is urgent to achieve spatially explicit estimates of habitat suitability for increasing cultivation of Jatropha. The opportunities and risks for Jatropha were evaluated under climate change using the minimum and maximum representative concentration pathways (RCP2.6 and RCP8.5) by 2100. The extent of predicted suitable habitats may shrink by more than 45%, regardless of time slices, and the RCPs even considered assuming the most optimistic ability of dispersal. The impacts of climate change vary considerably among continents with the greater habitat loss in the Americas and Oceania than in Asia and Africa, and a high risk of habitat loss at low latitudes. The findings indicate that Jatropha would show a decreasing opportunity for desired energy supply. Due to the complexities of the likely impacts of climate change, this study provides important insights into developing cultivation policies for the utilization of Jatropha within a sustainable biofuel program.

1. Introduction

Under the increasing pressure of the growing population and the impacts of climate change, producing renewable bioenergy has motivated accelerating interest all over the world with the declining availability of fossil fuels [1–3]. Biofuel crops are marked as the most important materials for producing bioenergy, and biofuel can be a substantial proportion of our future energy supply, especially for liquid biofuel [4,5]. Subsequently, many wild plant species have been cultivated for bioenergy production. Several of these species possess a strong adaptability, and they were introduced to different regions in recent decades [2,6–8]. These crops are mainly grown on marginal lands that are in relatively poor natural condition but are capable of supporting the cultivation of biofuel crops or on land that is not currently used for agricultural production but can grow biofuel crops [2,9]. However, given global food security and land scarcity concerns, biofuel crops raise additional attention because sustainable biofuel sources require sufficient marginal areas [10,11], and they may be detrimental to the regional ecosystems [6,12,13].

Moreover, the Intergovernmental Panel on Climate Change (IPCC) recently projected the sea surface temperature to warm from 1 °C [Representative Concentration Pathway (RCP2.6)] to more than 3 °C (RCP8.5) by 2081–2100, relative to 1986–2005 [14]. Biophysical environments, especially temperature, can control the rate of metabolic processes that ultimately constrain crop performance [15]. Therefore, the cultivation of biofuel crops would be affected by global climate change [16–19]. Predictions of how current habitats respond to climate change and where suitable habitats for cultivation would be located in the future can provide critical information for assessing the sustainability of biofuel crops as well as the desired opportunity for energy supply [7,16,19–22].

Jatropha curcas L. (further referred to as Jatropha) is considered as a high-potential for supplying renewable energy due to its seed oil with the matching characteristics of diesel [23–29]. The global demand for liquid biofuels, together with optimistic claims about Jatropha (e.g., achieving energy security and revitalizing marginal and degraded lands), triggered a massive promotion and implementation of cultivations in Asian (especially in India and China), African, and Latin

E-mail address: hujh@cib.ac.cn.

http://dx.doi.org/10.1016/j.rser.2017.03.093
Received 1 March 2016; Received in revised form 7 February 2017; Accepted 20 March 2017
1364-0321/

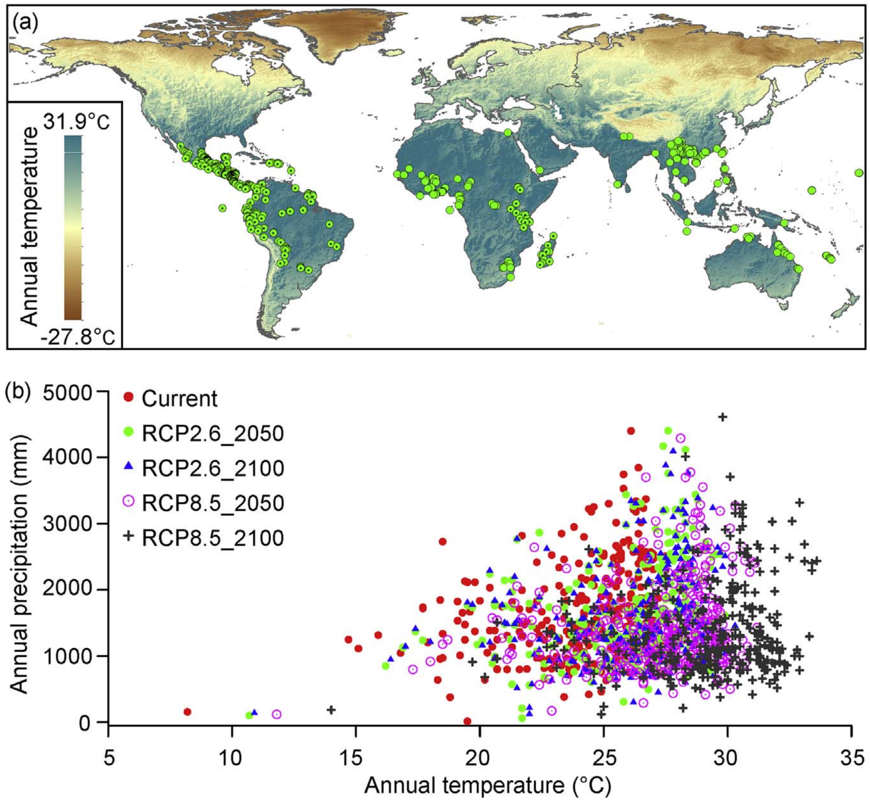

Fig. 1. Occurrence records of *Jatropha curcas* (a) and environmental conditions (annual temperature versus annual precipitation) for occurrences across RCPs and time slices (b). In panel (a), green circles indicated occurrence records (circles with dark spot for ecological niche modeling, and circles without dark spot representing the introduced cultivated distributions); the background represented the current annual temperature. In panel (b), RCP2.6 and RCP8.5 represented the minimum and maximum representative concentration pathway (RCP) by 2050 and 2100, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

American countries (Fig. 1a) [30,31]. Jatropha is expected to be cultivated on 12.8 million ha worldwide by 2015 [11]. However, a sustainable biofuel production program should not only provide a continuous and steady supply of biodiesel, but it should also substantially contribute to ecological, economic and societal development [26]. There is an urgent need to understand the habitat suitability for growing Jatropha not only with current climatic condition but also in a changing climate (Fig. 1b).

This study aimed to provide important insights into developing adaptation strategies and cultivation policies for the future sustainable utilization of Jatropha in a changing climate at the global scale. To achieve this goal, the impacts of projected climate change on habitat suitability for Jatropha were assessed spatially. Specifically, the global suitability of Jatropha was projected by 2100. Then, the expanded, reduced or retained suitable habitats were quantified. Finally, the study identified where climate change may have the greatest impact on the suitability and corresponding latitudinal shifts. The results would contribute to the further domestication and cultivation of Jatropha and to the planning, implementation and operational management of future bioenergy production.

2. Materials and methods

2.1. Study species and occurrence data

Jatropha is a perennial, deciduous, stem-succulent shrub. It is native to Mexico and Central America and distributed in Latin America, Africa, India and South East Asia (Fig. 1a). Jatropha is expected to grow and fruit in different types of lands without irrigation and agricultural inputs, and its seeds contain 40–60% oil [24,27]. Peculiar features of Jatropha include drought tolerance, pest resistance, rapid growth, easy propagation, and adaptation to a wide range of environmental conditions that make it a special candidate for the biodiesel industry [23].

Geographical occurrence records describing the natural distribution of Jatropha were retrieved from the Global Biodiversity Information Facility (GBIF; http://www.gbif.org/). The occurrences in the GBIF were retrieved from multiple sources; therefore, different geographical or ecosystem focuses were integrated to reduce the environmental sampling bias. Occurrences were double-verified in spreadsheets and geographic information system (GIS) to detect duplicates and georeferencing errors. Only the occurrences from the second half of the 20th century were retained to maintain temporal correspondence between occurrence and climate data. A final dataset was comprised of 466 occurrences, with only one occurrence per grid cell at the resolution of 2.5 arc-min. All of the occurrences were divided into two parts: one representing occurrences from Central America, South America and East Africa for model training (333 occurrences; circles with dark spot in Fig. 1a) and the other part representing the introduced cultivated distributions (133 occurrences; circles without dark spot) [16].

2.2. Predictor variables and future climate projections

Based on the tests of environmental variables describing soil, topographic and climatic conditions as explanatory factors for the fitness of Jatropha, only climate datasets should be inferred as significant and reliable responses [16]. Thus, only bioclimatic variables were selected in this study to estimate habitat suitability for Jatropha. Bioclimatic variables were obtained from the WorldClim 1.4 database [32] that represented the current (1950–2000) conditions. Due to the high levels of correlations between bioclimatic variables and the need for variables to be as proximal as possible, the initial variable set was reduced to a smaller subset by integrating the results of Pearson's