Agriculture, Ecosystems and Environment 171 (2013) 39–46

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

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

Identifying the areas to preserve passion fruit pollination service in Brazilian Tropical Savannas under climate change

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ARTICLE INFO

Article history:
Received 22 October 2012
Received in revised form 28 February 2013
Accepted 8 March 2013
Available online 17 April 2013

Keywords:
Agriculture
Apidae
Conservation
Forage plants
Pollinators
Xylocopa

ABSTRACT

The aim of this study was to identify future distribution areas and propose actions to preserve passion fruit pollination service under a scenario of future climate change. We used four species of *Xylocopa* bees that are important for passion fruit pollination in Brazilian Tropical Savannas. We also used the known forage plant species (33 species) that are associated with this same area, since passion fruit flowers provide only nectar for bees and only during their blossoming period. We used species distribution modeling to predict the potential areas of occurrence for each bee and plant based on the current day distribution and a future climate scenario (moderate projections of climate change to 2050). We used a geographic information system to classify the models and to analyze the future areas for both groups of species. The current day distribution map showed that *Xylocopa* and plant species occurred primarily in the southern and central-eastern areas of the Brazilian Tropical Savannas. In the north, *Xylocopa* species only occurred in a small area between the states of Maranhão and Piauí while forage plant species were only observed in the northern part of the Tocantins State. However, both future scenarios (bees and plants) showed a shift in distribution, with occurrence predominantly detected in the northern areas of Brazilian Tropical Savannas. Possible conservation areas and the use of appropriate agricultural practices were suggested to ensure the maintenance of the bee/plant focal species.

1. Introduction

Ecosystem services are the benefits delivered directly or indirectly to humans by natural ecosystems (Daily, 1997; MEA, 2005). Ecosystem services have been considered to be an important link between key scientific organizations, environmental policy bodies and research funding organizations (Larigauderie and Mooney, 2010), aiming to build the capacity to use science in policy making and decisions (Perrings et al., 2011).

Pollination is considered a key element of ecosystem services (Costanza et al., 1997; Daily, 1997). Ollerton et al. (2011) estimated that the proportion of animal-pollinated species is near 78% in temperate zone communities and 94% in tropical communities and that the global number of animal-pollinated angiosperms is near 300 000, 87.5% of the estimated species-level diversity of flowering plants. Pollination is also considered fundamental in ensuring the production of food because one-third of agricultural production depends on animal pollination (Kremen et al., 2007). Although the crops that have the greatest production volume (e.g. rice and wheat) are wind-pollinated, a large proportion of crops with high nutritional value (e.g. fruits and vegetables) are dependent of pollinators (Potts et al., 2010).

The decline of pollinators has been noted since the mid-1990s (Buchmann and Nabhan, 1996; Kearns et al., 1998). Recently, multiple drivers (including the loss and fragmentation of habitats, aggressive agricultural practices, pathogens, invasive species and climate change) were identified as the primary cause of this decline

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http://dx.doi.org/10.1016/j.agee.2013.03.003

(Potts et al., 2010; Schweiger et al., 2010). Climate change was proposed as the probable cause of pollinator decline in studies based on data from historical surveys of pollinators (Biesmeijer et al., 2006; Dupont et al., 2011).

Species distribution modeling (SDM) has been used to investigate the impact of climate change on the geographic distribution of species (Franklin, 2009). This tool has different names, such as ecological niche modeling or habitat suitability modeling. It uses the known occurrences of species and different environmental variables to define a set of suitable conditions under which the species can maintain viable populations (Peterson et al., 2011).

The data needed for SDM includes biological and environmental information. The best conditions of both datasets to perform SDM include the following features (Franklin, 2009): (1) Biological data (reported occurrence points): designed surveys often produce data that is more appropriate to SDM than random ones; larger samples improve models and can help to correct noisy and biased data; whenever possible, a balance of presence and absence data must be achieved; the extent of study area has to be a good representative of the real extent of distributional area; biological surveys can be repeated regularly and provide useful information about species distribution on different time periods; existing data provided by biological collection must be examined for spatial and taxonomic bias; since the distribution of most species are still poorly known, one of the main challenges is the lack of sufficient number of observations to perform SDM. (2) Environmental data (environmental layers): SDM can use broad scale climatic variables where extremes of temperature and precipitation are often more related to limited species growth and survival than annual averages; finer scales factors derived from topographic data can also be included; SDM for animal species can include predictors related to food or water availability, if applicable; vegetation type or landscape structure can also be used as predictors. SDM has been used successfully to guide searches for and discovery of unknown populations and occurrence areas of species; conservation application, aiming to provide effective guidance for conservation actions; projections of climate change impact; estimate susceptible areas to species invasion; determine the geography of disease transmission and; link ecological niches with evolutionary processes (Peterson et al., 2011).

With the goal of determining conservation areas, SDM has been used to investigate localities in which species will find suitable habitats in the future. For example, SDM was used to assess the adequacy of conservation areas to protect endemic birds (Marini et al., 2009) and odonates (Nóbrega and De Marco, 2011) in the light of future scenarios of climate change. SDM has also been used to define suitable habitats and identify potential areas for conservation of a threatened species (*Heloderma horridum*) (Domíguez-Vega et al., 2012) and to guide a restoration program for American chestnut (*Castanea dentata*) (Fei et al., 2012).

Certain crops are particularly dependent on bee pollinators. This is the case for passion fruit crops (Souza et al., 2004). The pollinator species richness (Yamamoto et al., 2012), abundance (Camillo, 2003) and frequency of visitation (Benevides et al., 2009) have been proved to increase the fruit set in passion fruit orchards. Brazil is the largest producer of passion fruit in the world, and its trade is important to the Brazilian economy, with most of the production based on *Passiflora edulis* Sims (Meletti and Brückner, 2001). The Brazilian production of passion fruit reached almost one million tons in 2010 (IBGE, 2011). Passion fruit flowers can be manually pollinated, but natural pollination is cost free and increases the quality and quantity of fruits (Roubik, 1995), providing higher income and giving value to this commodity. Furthermore, the crop is produced primarily by small farms and family farming (Meletti, 2011). These characteristics provide a good opportunity for the implementation of pollinator-friendly management in the light of agricultural practices and the impact of climate change.

Passion fruits are pollinated by large bees, usually species of *Xylocopa*, *Bombus*, *Centris*, *Epicharis* and *Eulaema* (Camillo, 2003; Hoffmann et al., 2000; Malerbo-Souza et al., 2002; Sazima and Sazima, 1989). *Xylocopa* Latreille, 1802 (Apidae) species are considered the most effective pollinators due to their size and foraging behavior involving the flowers (Sazima and Sazima, 1989). *Xylocopa* bees are also known as "carpenter bees" due to their nesting habit of excavating tunnels in wood (Hurd, 1958). However, passion fruit flowers provide only nectar (Camillo, 2003) and do so only during their blossoming period. Thus, bee species require extra sources of nectar in seasons other than the season in which the passion fruit are flowering and need extra pollen sources to feed their offspring. As a result, the pollinators depend on resources from other plant species. Therefore, the delivery of passion fruit pollination services depends on both the pollinator bees and the plants on which they forage.

The principal objective of this study was to identify future distributional areas for the *Xylocopa* bees as passion fruit pollinators and their forage plants in the Tropical Savanna areas of midwestern Brazil under a realistic climate change scenario.

2. Materials and methods

The study was performed in the area of Brazilian Tropical Savanna (BTS) (Fig. 1). We used the biome classification in Olson et al. (2001) to specify the study area. To characterize and discuss the status of current vegetation coverage of BTS, we used the database of Bontemps et al. (2010), which shows the global land cover for 2009. To depict the current conservation areas, we used a dataset available on the IBAMA (Brazilian Institute of Environment and Renewable Natural Resources) website. To determine the municipalities within BTS where passion fruit was cultivated during the last twenty years, we used an agricultural dataset available on the IBGE (Brazilian Institute of Geography and Statistics) website.

We chose the midwestern areas of Brazil because the interactions between passion fruit pollinator bee (Yamamoto et al., 2012) and forage plant species were determined in a previous field study that was conducted over a year in four localities inside BTS (Silva et al., 2010). Based on this previous study, we chose four *Xylocopa* species (*X. frontalis* Olivier, *X. suspecta* Moure & Camargo, *X. hirsutissima* Maidl and *X. grisescens* Lepeletier) and 33 plant species that were important sources of nectar and pollen for these bees (Silva, 2009) (see Table 1 for the list of plant species). These four species were considered as effective pollinators and presented a relative frequency of visitation of 12.8% (*X. frontalis*), 11.5% (*X. suspecta*), 1.3% (*X. grisescens*) and 0.2% (*X. hirsutissima*) (Yamamoto et al., 2012). Other effective pollinators in the same area were: *Acanthopus excellens* Schrottky (0.5%), *Bombus pauloensis* Friese (2.7%), *Centris denudans* Lepeletier (0.3%), *Centris scopipes* Friese (4.8%), *Centris sponsa* Smith (0.03%), *Centris longimana* Fabricius (1.2%), *Epicharis flava* Friese (0.5%) and *Eulaema nigrita* Lepeletier (0.3%).

To perform SDM, we compiled a dataset based on the literature and Internet data sources for the occurrence (see Appendices A1 and A2 for bees and plants data sources, respectively, and Appendix B for details about plant species). We also used 19 layers of bioclimatic variables that consider the temperature and precipitation averages of the last 50 years, with a resolution of 30″ (Hijmans et al., 2005). We used the same layers for the year 2050 in a future projection to address a scenario of climate change. This future scenario was created by the CCCMA (Canadian Centre for Climate Modelling and Analysis) (Ramirez and Jarvis, 2008) and includes a moderate climate change scenario (A1B – IPCC, 2001). The moderate scenario (A1B) seems to be more adequate to be used in this case study when one considers the storyline of Intergovernmental Panel of Climate Change (IPCC) and the Brazilian politic-economic