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Fire management and climate variability: Challenges in designing environmental regulations

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ABSTRACT

Designing fire management regulations is a challenging task given the spatial and temporal variation of climate conditions. Using the burning calendar, a fire management tool to prevent forest fires in Mexico, we assessed the temporal and spatial overlap between this regulation, climate variability and fire use in Calakmul, Mexico. Based on technical recommendations and fieldwork, we defined ranges of wind speed, relative humidity and rainfall that are needed for burning. We studied how these conditions varied over periods of 10 to 50+ years based on meteorological records in 5 locations. Participant observation of agricultural burns and interviews with community leaders and government officials allowed us to study the challenges of following regulations. Results indicate that during the legal time to burn, from 4 to 11 am, there is, on average, only 1 h with suitable climate conditions for agricultural fire. Farmers burn in the afternoon, when moisture is lower, increasing the chances of successful agricultural burns to 25% and up to 80% compared to morning conditions. However, in the afternoon, wind speed tends to increase, elevating the likelihood of uncontrolled secondary fires. In terms of seasonality, the period to burn is suitable for some years in some locations but it is not infallible. Environmental rules aimed at fire management must be sensitive to local climate variations in order to achieve both wildfire prevention and support livelihood systems relying on fire. Rules that do not correspond to the physical context are not only less likely to be followed, but are not legitimate to actors whose behaviors are intended to be regulated.

Introduction

The burning calendar is a fire management tool used in the State of Campeche, Mexico, to regulate the timing of fire use in agricultural, livestock and forestry activities. We examine the degree to which this calendar, whose legal foundation is grounded in the state burn law, corresponds with the local climatic conditions required for burning. The state specifies the official burning periods based on regional climatic conditions; however fire behavior is determined by local weather and fuel loads. Farmers consider several factors to decide the time of agricultural burns. They take into account climatic conditions, such as humidity and wind speed, as well as stages of the moon and other beliefs (Mistry, 1998). Farmers also incorporate elements such as their knowledge and experience, the status of their pre-burn activities in the plot, and the formal and informal rules that regulate fire management. In this sense, designing, implementing and monitoring fire management institutions is complex given that fire behavior is influenced by physical conditions like topography, land cover and climate, but it is also defined by the local management decisions which are constrained by norms, knowledge, and resources (Román-Cuesta et al., 2003; Alencar et al., 2004; Carmenta et al., 2011; Sorrensen, 2004, 2009).

Fire is an essential element in tropical subsistence agriculture and is an effective tool to release nutrients and eliminate undesirable vegetation and pests at a low cost to farmers. Controlling fires from spreading to other areas is difficult in certain conditions. Droughts combined with strong winds can lead to secondary outbreaks of fire that spread and affect large areas of surrounding forest (Johnson and Dearden, 2009; Sorrensen, 2004). Governments establish rules to conserve natural resources and to reduce the chances of unwanted forest fires. Some large developing countries, such as Madagascar and Indonesia, prohibit and criminalize the use of fire (Kull, 2004; Tacconi et al., 2007), but others, such as Mexico, allow its regulated use (Rodríguez-Trejo and Fulé, 2003).

In Campeche, home to the Calakmul Biosphere Reserve and a municipality of the same name (Fig. 1), the state regulates agricultural burns through a "Burning Calendar". In order to comply with

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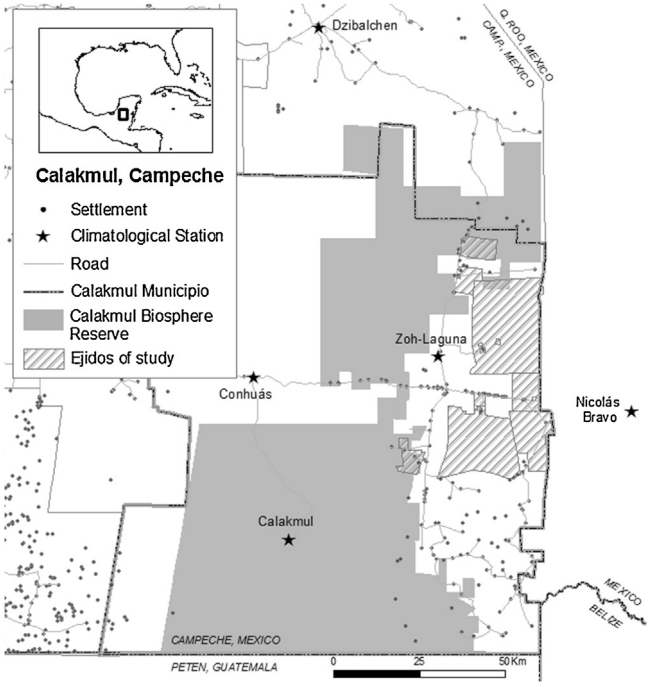

Fig. 1. Location of Calakmul, climatic stations and ejidos of interest.

the calendar, farmers are required to ensure that cutting, felling and drying of vegetation, are completed before the beginning of the burning season. Although farmers can organize their time and labor resources, they cannot control the atmospheric conditions that dictate the date and time of burn. Timing is nonetheless regulated by the state, posing a complex issue of compliance with environmental rules. Under these circumstances, farmers face not only climatological and meteorological variability that challenges their subsistence objectives, but are also subject to sanctions if burns occur outside the officially prescribed burning season. Furthermore, climate variability poses a problem for authorities since rules designed to control and regulate an activity do not reflect local conditions and consequently, farmers may perceive regulations as impossible to follow, hence diminishing institutional legitimacy.

This paper, examines the correspondence between the official burning calendar and the local conditions for burning in Calakmul, Mexico. More specifically, we examine what is the probability of recording the weather conditions necessary for an agricultural burning during the time of day and for the dates that the law prescribes. In addition, we examine to what extent weather conditions vary within the municipality of Calakmul and how this variation affects the probability of recording appropriate physical conditions for burning. Using information from weather stations, we assess the temporal and spatial overlap between the burning calendar, the local climatic conditions and the feasibility of using fire. The challenges to following regulations locally were identified through participant observation of agricultural burns and interviews with farmers, community leaders and government officials. By studying fire management, this study analyses the match between policy, environmental context, and human behavior.

Background

Environmental governance addresses the role of institutions in shaping environmental outcomes. Institutions are "the normative rules that control the timing, spacing and character of resource use, but also the culturally and politically situated authority systems that monitor and enforce these rules." (Robbins, 1998, p. 412). Thus, institutions are forces or exertions of power that can influence human–environment interactions. We approach institutions as dynamic and divisive, and frame them as a result of processes of resistance and struggle in which individual agents redefine and reinterpret the normative principles that regulate behavior (Dietz et al., 2003; Robbins, 1998).

One of the challenges of environmental governance is to identify and manage the complexity that underlies the ecological and social processes (Ostrom, 2007; Cash et al., 2006; Berkes et al., 2003; Holling, 2001). In words of Elinor Ostrom (1995, p. 34), "If complexity is the nature of the systems we have an interest in governing (regulating), it is essential to think seriously about the complexity in the governance systems that are proposed". Besides developing multilevel institutions for the multi-scale ecosystem management, institutions must be aligned with biophysical dynamics and take social systems into full account (Galaz et al., 2008). The degree to which the attributes of institutions and wider governance systems at local to global levels match the dynamics of biophysical systems is referred as the problem of fit (Galaz et al., 2008). The concept of institutional fit and misfit was first introduced in 1998 by Folke et al. (2007), and along with the concepts of interplay and scale, constitutes one of the three analytical themes that guided the research of the Institutional Dimensions of Global Environmental Change (Young, 2008).

Institutional misfits arise due to designing and implementing simple, large-scale, centralized management approaches that ignore the complexity of human–environment coupled systems (Ostrom, 1995; Brown, 2003). Misfits between regulations and socio-ecological systems are associated with an inability to consider (1) the scale and cross-scale dynamics in human–environment interactions (Cash et al., 2006), (2) the physical environment in which the commons are located (Agrawal, 2003) and (3) the interplay of different forms of power and micro-politics (Robbins, 1998; Haenn, 2002; Agrawal, 2003). Problems of fit derive from three aspects of conventional management approaches: they tend to have narrow, poorly defined, or conflicting objectives; they attempt to suppress variability and block out the disturbance, which paradoxically increases the chances of large-scale disturbance; and they have short-term rather than long-term goals (Brown, 2003). Failure to acknowledge the complexity of scales and levels may explain the occurrence of unexpected events within the human–environment interactions and environmental governance (Kates and Clark, 1996; Cash et al., 2006).

Study site

This study takes place in Calakmul Municipality, located in southeastern Campeche, Mexico (Fig. 1). The area is covered by a seasonal semi-evergreen tropical forest which, along with the Guatemalan Petén and Belize's jungle, constitutes the Maya forest, one of the three major forest areas of Mesoamerica (Bryant et al., 1997). The region is characterized by karstic subsoils with subtle changes in elevation (100–350 m) and pronounced seasonality (Kopen: Aw2). Rainfall records in the community Zoh-Laguna (officially Alvaro Obregon, locally Zoh-Laguna), located in the east of the municipality, indicate that annual precipitation there is 948 mm of which 65% falls during the rainy season, from June to October (Márdero et al., 2012). This area is also characterized by a midsummer drought during July and August known as *canícula* (Magaña et al., 1999). The driest months from November to April register, on average, less than 2 mm of daily rainfall (Márdero et al., 2012). In addition to the seasonal variation, this region has a spatial variation of humidity; the southeast area of the peninsula is more humid than the northwestern (Turner et al., 2001). These spatiotemporal patterns modify the humidity content of the vegetation present in the region which plays a major role in fire occurrence.