Agricultural Systems 149 (2016) 99–111

Contents lists available at ScienceDirect

Agricultural Systems

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

Learning from commercial crop performance: Oil palm yield response to management under well-defined growing conditions

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ARTICLE INFO

Article history:
Received 10 February 2016
Received in revised form 31 August 2016
Accepted 3 September 2016
Available online 11 September 2016

Keywords:
Oil palm
Weather
Yield
Commercial data
Water deficit
Excess water

ABSTRACT

Farmers learn from their own experiences. However, they are rarely sure if an exceptionally good or bad outcome is due to chance effects or whether it is due to a given combination of management practices and environmental conditions. We surmised that, if each harvest event is adequately characterized and a large number of these events are analyzed together, it should be possible to associate crop response to management within a particular set of growth conditions. We tested this hypothesis using the perennial crop, oil palm.

The characterization of the harvest events can be divided into factors the grower can control (CFs), and non-controllable factors (NCFs). Expert opinion, coupled with literature reviews, indicated that the most important NCFs for oil palm in the humid tropics were surplus water and water deficits in the three-year period before and including the year of harvest. Water deficit was assessed using a simplified water balance model with inputs on inherent soil characteristics and rainfall. Surplus water was evaluated from the rainfall, inherent soil characteristics and the topographical position of the block in question. Homologous events (HEs) with similar NCFs were determined from weather and soil data for 141 blocks covering >6000 ha over the period 2007–2013 on a commercial plantation.

The yield of fresh fruit bunches (FFB) of 262 blocks over the period 2009–2013 was analyzed on the conceptual basis that if HEs can be defined in terms of growing conditions and used to account for part of the yield variation (NCFs), then the remaining variation within these events can be attributable to controllable factors (CFs) or management practices. Inclusion of HEs for the three years before the harvest year improved models used to explain yield variation. The variations in yield were in accordance with the expected effects of the distinct HEs confirming their validity as an analytical tool with normal conditions giving the highest yields, either deficit or surplus water giving intermediate yields, and a combination of both deficit and excess water the lowest yields.

We chose the CF of fertilizer response to associate variation of management practices and yield within and across HEs. The overall response to fertilizer at 12.8 kg FFB·kg^{-1}, without including HEs in the model, was much greater than that obtained when HEs were included (5.9 kg FFB·kg^{-1}). As most data were from blocks with sup-optimal growing conditions, the response to fertilizer over the ranges used was small and under the poorest HEs was not detectable.

1. Introduction

Farmers and plantation managers base their decisions on how to manage their crops principally on recommendations from extension agents and experts, their own experience and that of their neighbors. However, due to the limited extent or range of their own experience they have difficulties relating a particular practice or experience to a particular set of conditions. Thus farmers are rarely sure if an exceptionally good or bad outcome is due to chance effects such as a favorable weather and soil combination or whether it was due to a given combination of management practices. The experts and extension agents tend to take information derived from both controlled experiments carried out in similar conditions or in the same recommendation domain (Norman and Collinson, 1985) and also their own experience, which they then use to advise or instruct farmers on how to grow their crops. This process can lead to: (i) selection of technology by researchers which does not do well under real conditions and is therefore

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http://dx.doi.org/10.1016/j.agsy.2016.09.002
0308-521X/

rejected by farmers; (ii) the rejection of technology by experts because it did not perform well in trials, but might have done well under commercial conditions; and (iii) the adoption of successful technology (Francis and Hildebrand, 1989). Furthermore, recommendation domains may be poorly defined, or the precise conditions of a block or field do not coincide with a specific recommendation domain. Hence, inappropriate recommendations are often made by experts (although they are unlikely to admit it!).

Both the experts using information from scientific, controlled experiments, and the farmers face the same difficulty of not knowing precisely when the results arising from their experiences will be repeatable in other circumstances. These problems can be resolved, at least partially, if a very large number of controlled experiments are executed and the crop in question is grown in relatively homogeneous conditions over wide areas. Irrigated, puddled rice is often grown under similar conditions over a wide area, and thousands of controlled trials have been planted and analyzed to determine which practices work, and which do not, and the results compiled in handbooks and production guides (Rice Knowledge Bank, 2016). In long growth cycle perennial crops like oil palm, that are normally not irrigated, the variation in growing conditions is large. It is difficult and costly to carry out experiments to determine the effects of myriad distinct practices that cover both the range of conditions under which the crop is grown and the distinct aspects of the crop response as the palms grow older. There are simply not many handbooks based on a massive knowledge base that effectively describe how to grow and manage oil palm. Hence, oil palm managers do not have at hand the same level of information as there is for crops such as rice, and they frequently have to make decisions from a limited knowledge base.

Faced with these difficulties, the International Plant Nutrition Institute (IPNI) is looking at novel means of determining the optimum practices for oil palm in Southeast Asia. The approach taken was to complement the information obtained from controlled trials and experiments with the massive amount of information collected by plantations on commercially managed blocks (Cook et al., 2014). The conceptual basis behind this methodology is that each block planted, managed in a particular manner and harvested is a unique event. If each event is adequately characterized and a large number of these events are analyzed together it is possible to associate crop response with variation in the growing conditions (Jiménez et al., 2009, 2016; Cock et al., 2011).

The variation in growing conditions is due to what we denominate as controllable factors (CFs) and non-controllable factors (NCFs). Variation due to NCFs is defined as variation which the farmer or manager cannot readily manage or control: this variation includes such factors as topography, local hydrology, inherent soil traits, and weather. Variation due to CFs refers to all those aspects that a grower can manage (Cook and Bramley, 1998; Jiménez et al., 2016): inter alia these include soil fertility and nutrient status, planting density, genotype of the crop, pest control and management, drainage, irrigation, and harvesting methods and protocols. In un-irrigated mature oil palm plantations, with which we were working, there are relatively few CFs; the most important are fertilizer and soil nutrient management, phyto-sanitary practices and harvesting procedures. Effectively such variables as plant population, plantation age and genotype are fixed at planting and are non-controllable for the 25 years or more of the crop cycle.

Experience with other crops suggests that analyzing data from commercial production with varying management practices to associate specific management practices (CFs) with yield is only viable when growing conditions (NCFs) are relatively homogeneous (see for example Cock et al., 2011; Jiménez et al., 2016). In Chile and Australia, the CropCheck system has been successfully used to determine which crop management factors are associated with high yield without taking into account variation in the growing environment (Araya et al., 2010; Lacy, 2011). This approach is effective under relatively uniform conditions, but is unlikely to be effective when conditions are heterogeneous. One of us found that analysis of commercial data to determine which sugarcane variety yielded most was not effective until the area was divided into homologous agro-ecological zones (Cock pers. com.). However, if a data set is compiled with both the CFs and NCFs characterized, it should be possible to define groups that are relatively homogeneous in terms of NCFs, and relate yield response to the management practices in each of these sets of homologous conditions. The approach of defining homologous events, in which NCFs are relatively similar, greatly enhances detection of the differential effects of management factors for specific conditions (Isaacs et al., 2007; Jiménez et al., 2009; Cock et al., 2011; Jiménez et al., 2011, 2016).

In the *Plantation Intelligence*® program (Cook et al., 2014), as a first step to analyzing commercial yield, we decided to develop a methodology for determining homologous events (HEs) with similar NCFs for oil palm. Once defined, HEs would be used to analyze the commercial data and associate yield response with specific management practices under well characterized environmental conditions. Previously, most efforts to classify NCFs have concentrated on climate and soil conditions, without taking into account the year to year variability of weather conditions and how these interact with the soil and the topography of the area. The definition of homologous events in oil palm is fraught with complications related to variation in weather conditions. The yield formation process is of the order of three years, starting with initiation of the inflorescence, followed by sex determination, abortion, pollination, and finally filling of the fertile fruits (Breure, 2003; Lim et al., 2011). Hence, for two events to be considered homologous, the NCFs during those three years must be similar. This is relatively simple for such factors as inherent soil characteristics and topography, which vary little over time. However, with such factors as rainfall (which influences drought, waterlogging and flooding events) and solar radiation, complex patterns exist over time and these have to be taken into account when evaluating the similarity of growing conditions over a three-year period.

This paper describes the development of a methodology for defining HEs in oil palm and then uses this methodology to demonstrate management effects on yield under well-defined conditions.

2. Methods

Most oil palm is grown between 15° N and 15° S at altitudes below 1000 m in areas with rainfall of 2000 mm or greater. Seasonal and spatial variation in temperature is small within this range of conditions and is not taken into account. Furthermore, the cloudy conditions associated with high rainfall limit the variation in solar radiation, which tends to be around 15 $MJ \cdot m^{-2} \cdot day^{-1}$ in ideal conditions for growing un-irrigated oil palm (Corley and Tinker, 2016). The variation is considerably less than in lower rainfall areas with radiation typically of order of 15 $MJ \cdot m^{-2} \cdot day^{-1}$ in the wet season and 19–20 $MJ \cdot m^{-2} \cdot day^{-1}$ in the dry season (see for example Baradas, 1980) and up to 25 $MJ \cdot m^{-2} \cdot day^{-1}$ with minimal cloud cover (estimated from Solargis, 2016.) Due to the limited variation, solar radiation is not directly taken into account. Furthermore, the methodology does not consider irrigated oil palm in which case solar radiation may be more variable depending on the season.

The overall methodology is summarized in Fig. 1.

2.1. Data collection

Both spatial (topography maps in the form of digital elevation models, soil maps) and non-spatial data (basic site information, rainfall and soil survey data, and crop management, performance and yield data) were collected from an estate of a commercial plantation in Central Kalimantan, Indonesia. The data were for 141 individual blocks with a total area planted to palm of >6000 ha. Monthly rainfall data were collected for the period 2004–2013. Soils were surveyed in June 2007 by Param Agricultural Soil Surveys (M) Sdn. Bhd. The fresh fruit bunch (FFB) yield and management data were collected from 2007 till 2013.