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Intermittent irrigation in the Waimea Field System, Hawai'i Island: A computational fluid dynamics model

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ABSTRACT

In pre-European contact Hawai'i, flooded irrigated agricultural systems were developed in wet windward areas with rain-fed dryland systems dominating leeward zones. In select areas lacking sufficient rainfall for dryland production, irrigation from intermittent streams would have been a viable alternative. A number of intermittent irrigated agricultural systems have been recorded in leeward Hawaiian locations, with the ca. 33 km^2 Waimea Field System being the most extensive. We use computational fluid dynamics modelling within a digital elevation model based on high resolution terrestrial laser scanning data to investigate intermittent irrigation within a 2.4 ha study area of the Waimea Field System. The analysis documents variation within channels and terraces. Some channels are gradual downslope ditches with the potential to irrigate large areas via garden plot flow through. Feeding off of these ditches are channels running parallel to slope with constrained flows of higher velocity that fed lower terraces without depositing water on upper terraces. The system also included channels running along the front of terraces that redirected flows horizontally across slope by collecting excess water. Terraces varied in terms of the amount of water that they could receive. Many terraces received moderate volumes of water, whereas select terraces in the valley bottom received much higher volumes and were probably used to grow water demanding crops. Other terraces were not fed by channels and were probably used for rain-fed agriculture or residential purposes. Documenting variation within this small section of the Waimea field system provides an understanding of diverse agricultural practices and how these were used for subsistence and surplus production.

1. Introduction

Pre-European contact Hawaiian agriculture is often divided into two broad classes, irrigated wetland systems and rain-fed dryland systems (Kirch, 1994; Ladefoged et al., 2009; Lincoln and Vitousek, 2017). The focus of pondfield irrigation was taro (*Colocasia esculenta*) production, with the creation of large flat flooded intensified systems in areas with consistent and plentiful water (Kirch and Kelly, 1975; McElroy, 2007; McCoy et al., 2011). The sustainability of these systems was in part ensured by nutrient flows into the ponds by water irrigation (Palmer et al., 2009). In contrast, rain-fed dryland systems were developed in large yet restricted zones on leeward slopes. Cultivation in these systems focused on sweet potato (*Ipomoea batatas*), dryland taro, yams (*Dioscorea* spp.), and sugarcane (*Saccharum officinarium*), with limited zones of breadfruit (*Artocarpus altilis*) in some systems. The intensified dryland systems were primarily restricted to the leeward sides of the younger volcanic islands where sufficient soil nutrients were distributed as a function of geologic substrate age, rainfall levels, and temperature (Vitousek et al., 2014; Ladefoged et al., 2009). In addition, Kurashima and Kirch (2011) note that areas of rain-fed production were also possible on colluvium slopes in valleys with the rejuvenation of soil nutrients via the deposition of younger geologic material.

The dichotomy between irrigated and rain-fed systems masks variability within, between, and outside these classes of agriculture. Several studies in Hawai'i have documented an alternative practice of floodwater irrigation, where water was intermittently distributed over agricultural plots to augment insufficient rainfall. Irrigation in these systems was required when rainfall was below a critical level for rain-fed production. Ladefoged et al. (2009) suggest that the minimum rainfall requirement for intensified rain-fed production was 750 mm/yr. In their study, this level was a proxy for crop growing season rainfall requirements and was partially determined by the distribution of rain-fed dryland agricultural features in the Leeward Kohala Field System based on the rainfall estimates of Giambelluca et al. (1986). More

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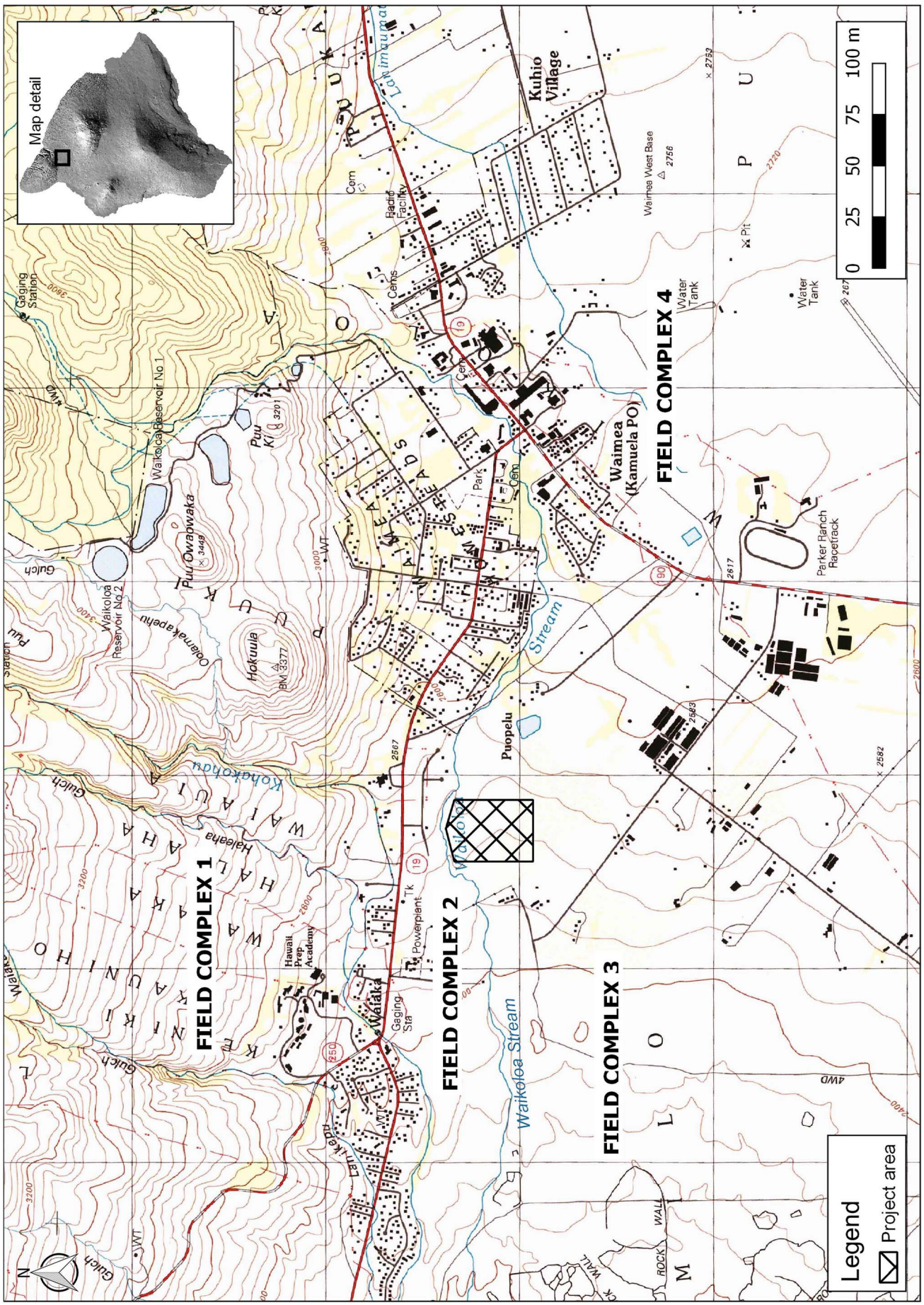

Fig. 1. Location plan of the current project area in relation to the Waimea township and Clarke's (1981, 1983) field complexes.