The Development of Wetland Agriculture in a Windward Hawaiian Valley: Evaluating Factors of Risk, Effort, and Production Output in Wailau, Moloka‘i

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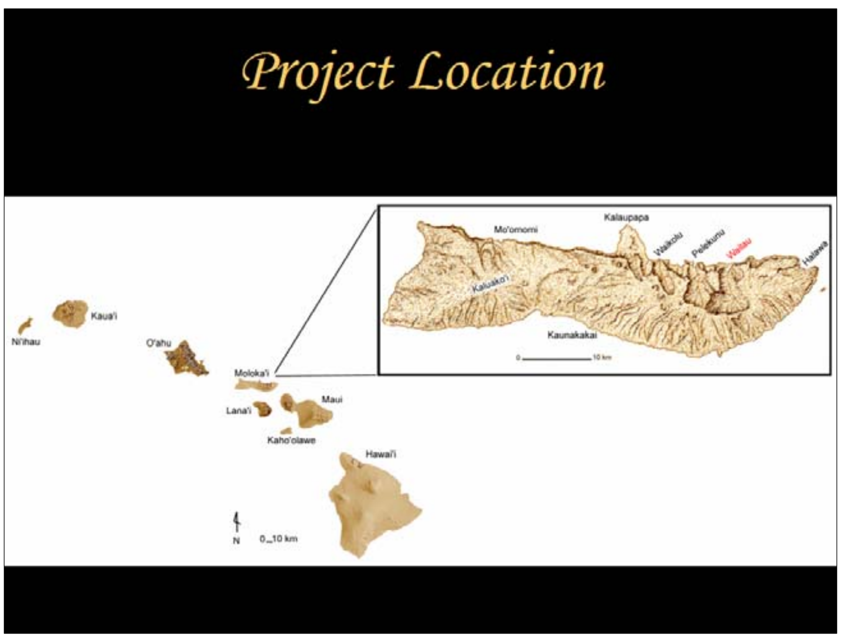
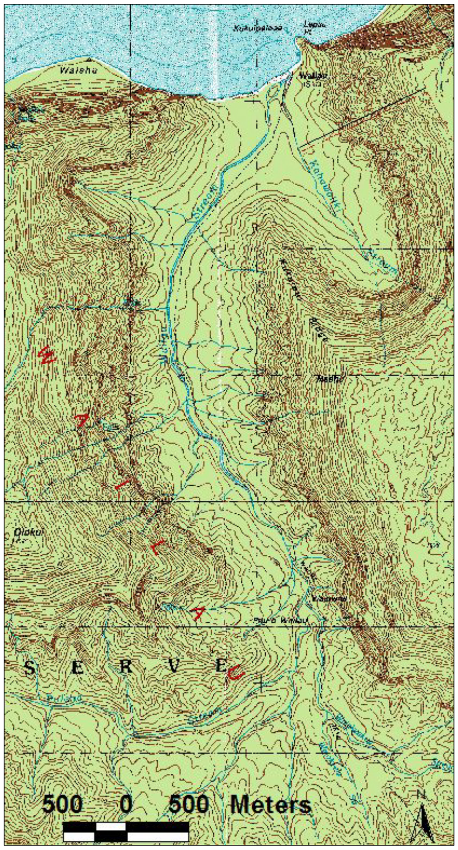
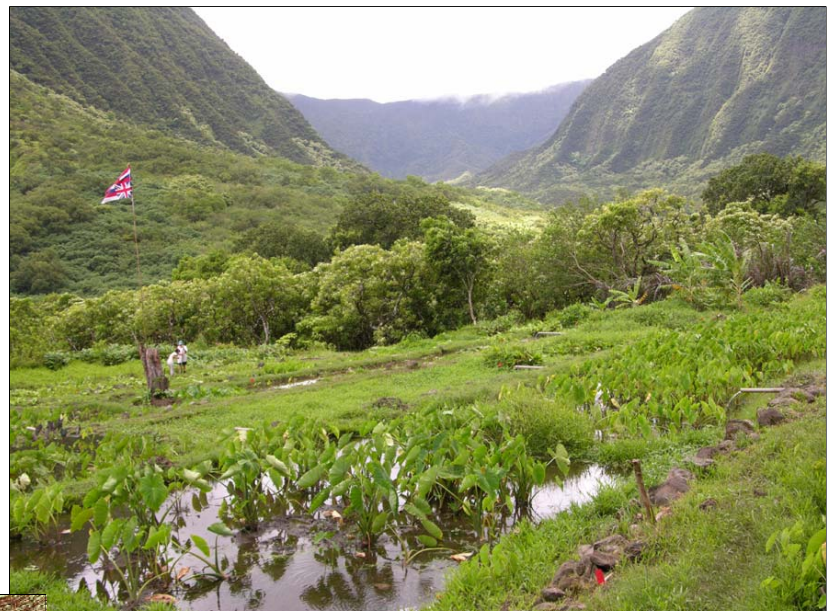
Introduction



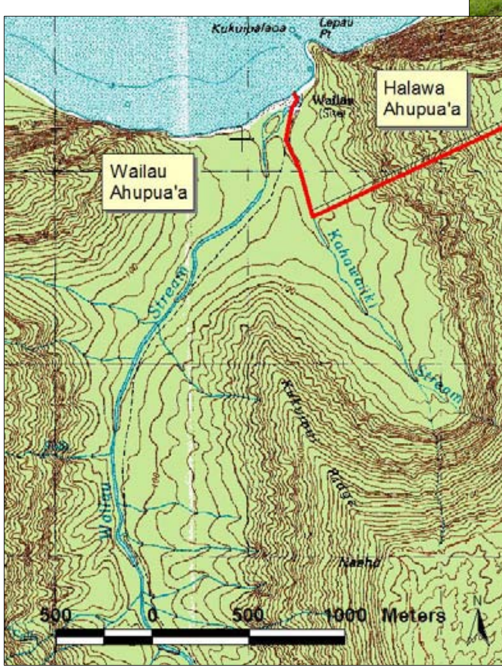
Wailau is the largest of four valleys on the wet windward coast of Moloka‘i, that stretches from Hālawa Valley on the east to Kalaupapa Peninsula on the west. Wailau Valley was a major area of taro production in the pre-contact era until the 1930s when the valley was abandoned.



Wailau is made up of this smaller broad valley on the east and a deeper valley on the west, with two major streams flowing down – Kahawaiʻiki Stream on the east side and Wailau Stream on the west.



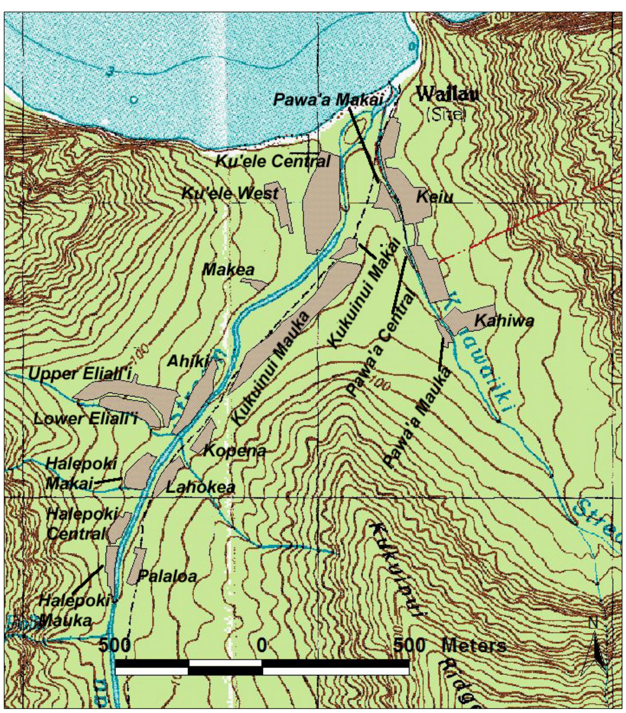
A series of intact irrigated taro fields, or *loʻi*, forms an agricultural system distributed across almost the entire 936-ha valley. Trails, habitation remains, and ceremonial structures are part of the cultural landscape as well.



A unique thing about Wailau is that the valley is made up of two *ahupuaʻa*, or community territories. The large western portion comprised Wailau Ahupuaʻa, while a small strip of land on the east was part of Hālawa Ahupuaʻa, which extends east all the way to Hālawa Valley.

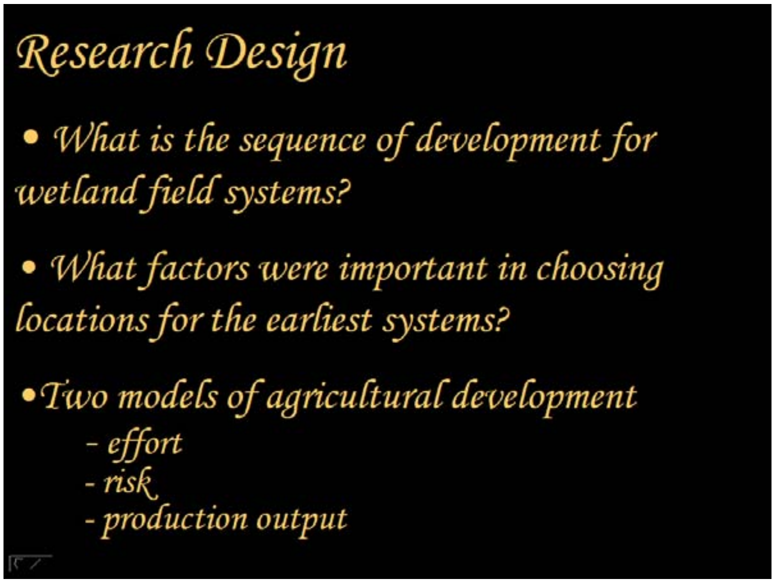
Wailau is very remote – there are no roads going in or out, no electricity, no running water, no cell phone service. We get to the valley by boat and camp out the whole time we're there.

Because of its inaccessibility, Wailau hosts few year-round residents and has escaped the widespread development that has destroyed many of the archaeological resources in other parts of Hawaiʻi. It is this rare condition that makes the valley a prime source of information about the past, although surprisingly little archaeology has taken place there.

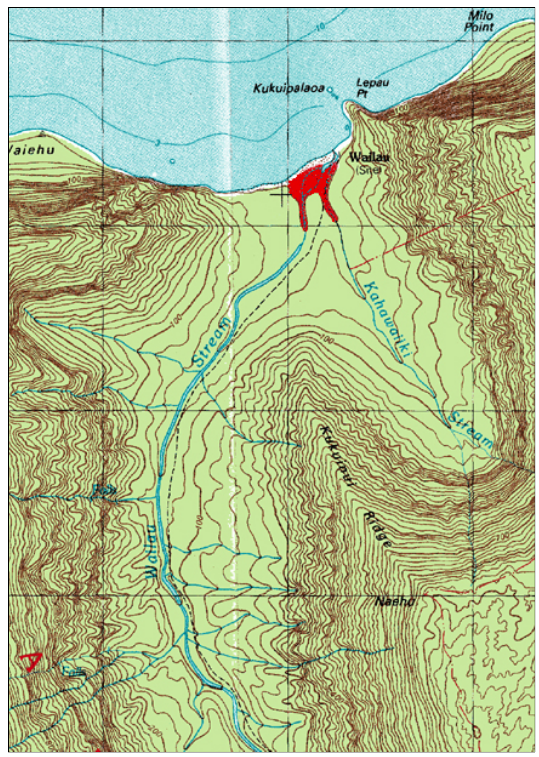


My work focuses on the irrigated taro field systems, or *loʻi*, of Wailau and I surveyed more than 100 ha of the valley and identified 19 *loʻi* complexes from the coast to approximately 2½ km inland. This map shows the names of the 19 identified *loʻi* systems.

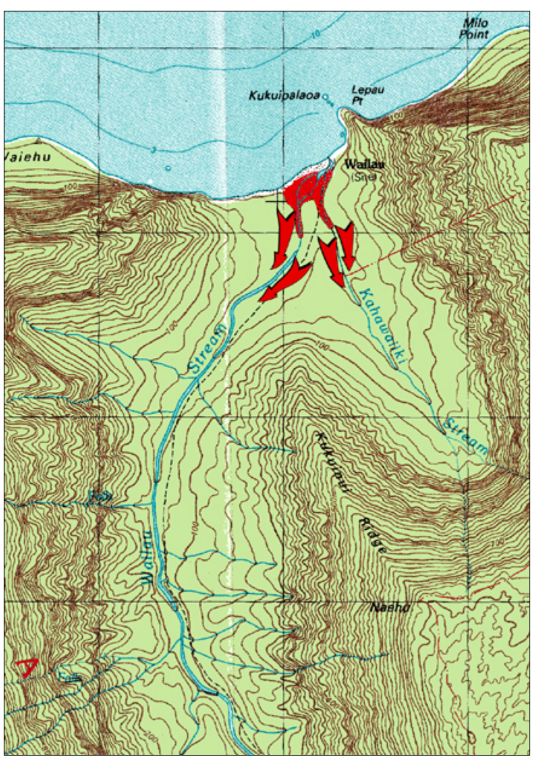
Research Design



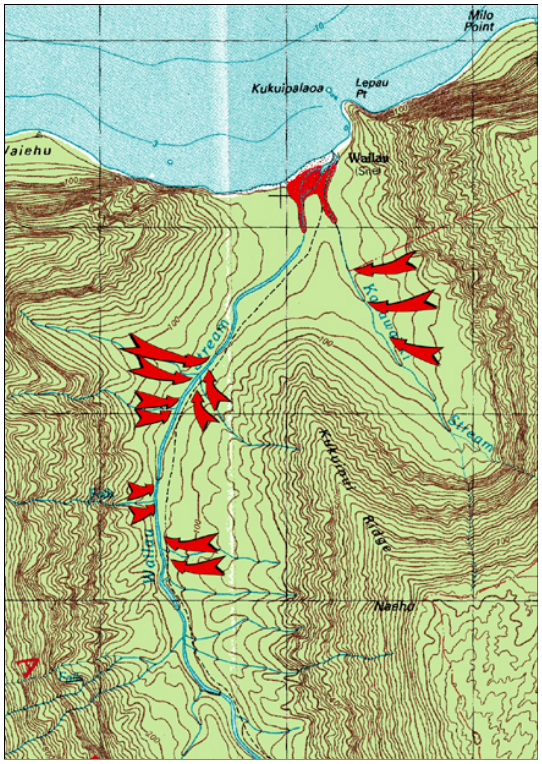
I’m asking 2 basic questions with this research: What is the sequence of development of the irrigated agricultural systems in Wailau Valley; and What factors were important in choosing locations for the earliest systems. There are two general models for wetland agricultural development in Hawai‘i, and I wanted to see if either model was applicable to Wailau. The models involve factors of effort, risk, and production output,



and both start with the earliest fields near the coast, where marine resources can be easily exploited, and where fields can be constructed in naturally-occurring low, wet spots with minimal effort.



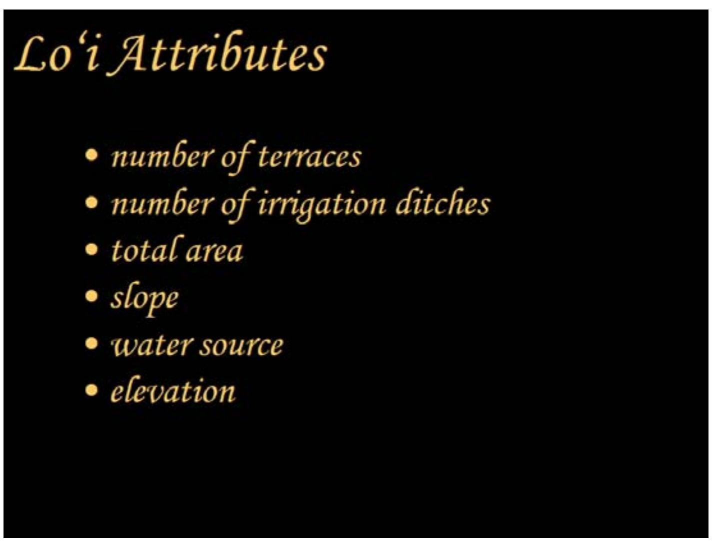
From there, the first model sees expansion starting along the main streams where the largest areas would be next developed. Agricultural complexes on the large flats along the main streams would be more difficult to build and maintain because of their size, and they would also be more risky, because of the danger of flooding. The returns, however, are equally large.



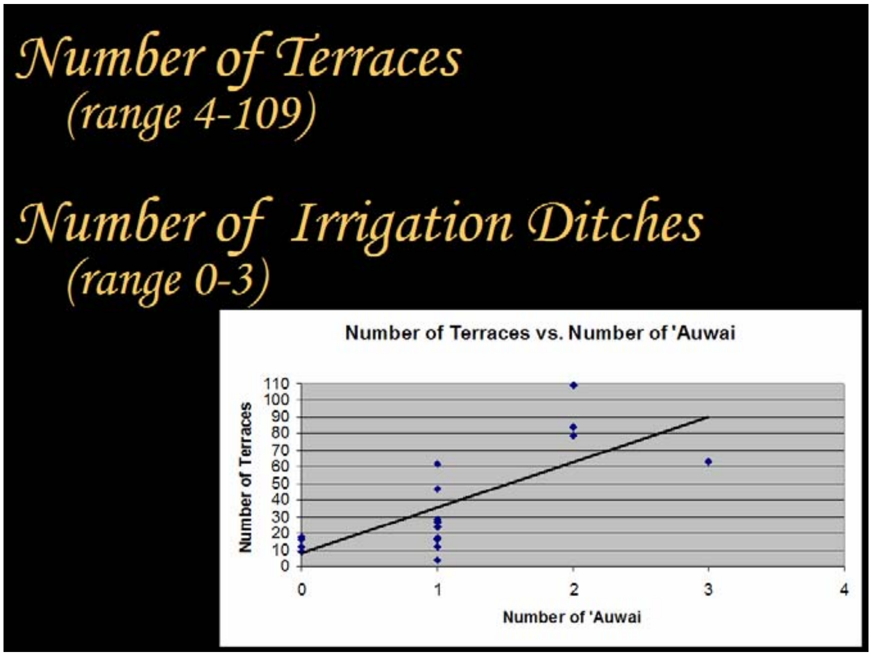
The second model sees the earliest expansion out of the valley bottom, along side drainages and shorter watercourses. Fields would be smaller here, easier to maintain, and less subject to flooding. These systems on the slopes would require the least effort to build and maintain and involve lower risk, but output would be less than larger fields near the main streams.

So, in short, this study will determine if fields were extended directly inland from the coast to optimize production despite increasing effort and greater risk; or if farmers first extended their fields to the valley slopes, which involved less risk and effort to construct and maintain terrace systems but produced lower crop yields.

Lo‘i Attributes

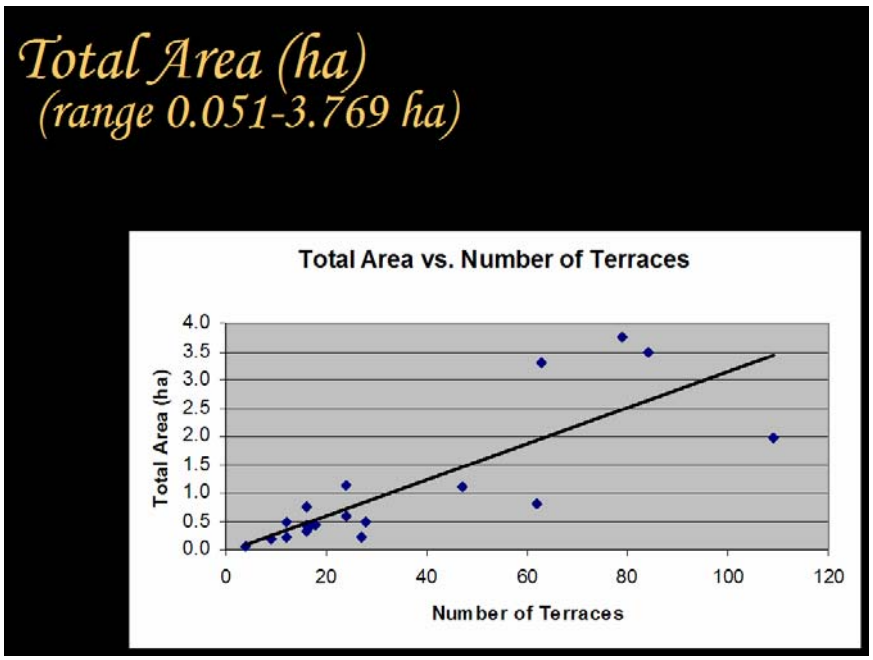


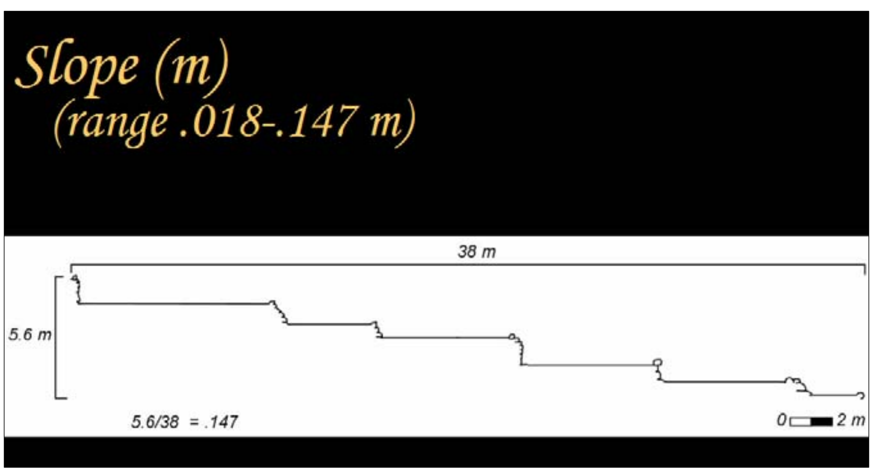
To test which model of agricultural development applies to Wailau, the first thing I did was to look at these attributes for the different *lo‘i* systems: number of terraces, number of irrigation ditches, total area of a complex, the slope of the land that the system is on, water source, and elevation.



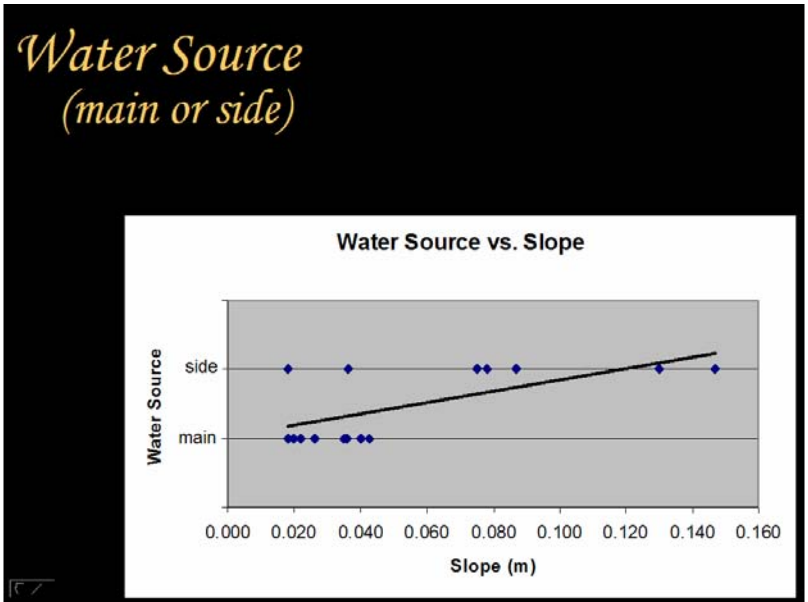
The number of terraces within each complex ranged from 4 to 109, and the number of irrigation ditches ranged from none to 3. In this graph, each dot represents one field system, and you can see that the complexes with fewer terraces had fewer ditches.

Complexes ranged in area from .051 ha to 3.769 ha. The smallest systems tended to encompass the fewest terraces. This indicates little variability in the size of individual terraces between the systems.



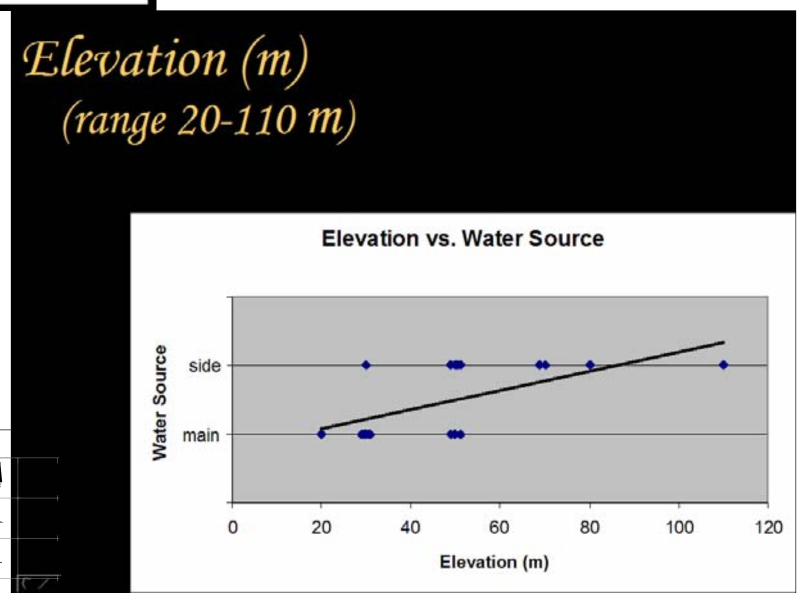


Slope was calculated by dividing the total height of a field system by its total length. Slope ranged from .018 to .147 m.

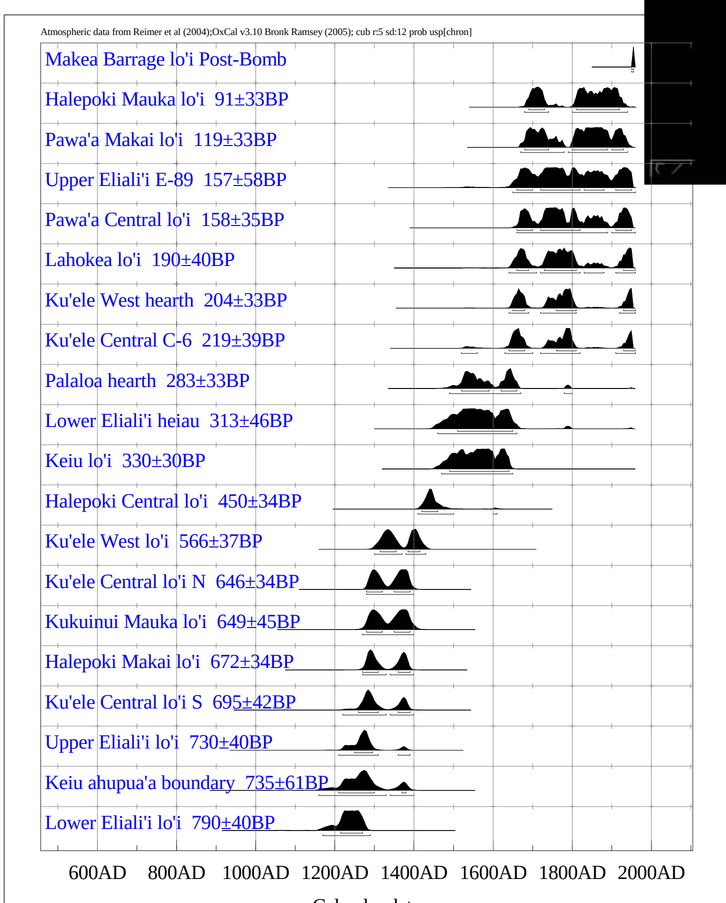


The water source attribute refers to the stream that irrigates each *lo‘i* system. Complexes were fed by the two main streams, Wailau and Kahawai‘iki, and various secondary drainages, referred to here as side streams. Complexes along the main streams tended to be more gradually sloping than those along the side tributaries.

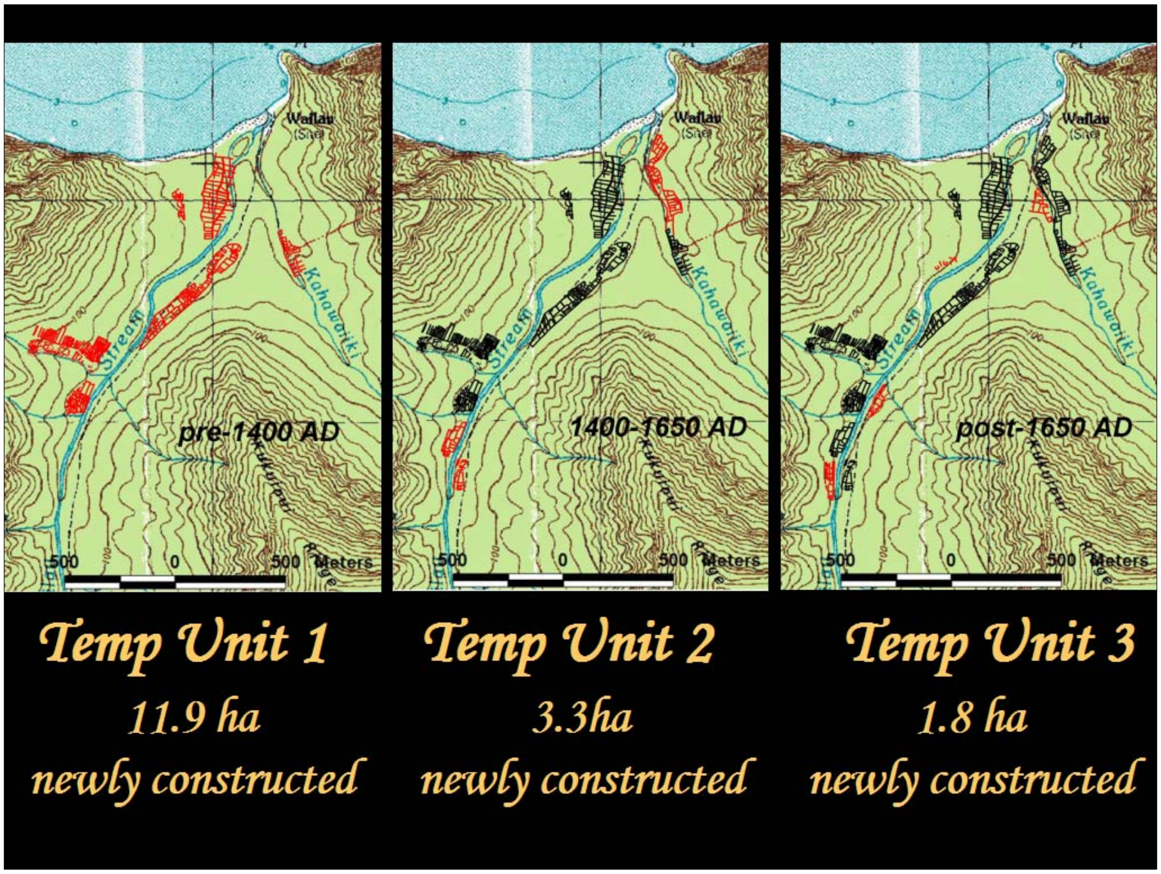
The final attribute was elevation. This ranged from 20–110 m above sea level. More low elevation complexes were watered by a main stream, and more high elevation ones were fed from side streams. This makes sense, as there is a smaller gradient along the main streams than the side drainages.



Dates



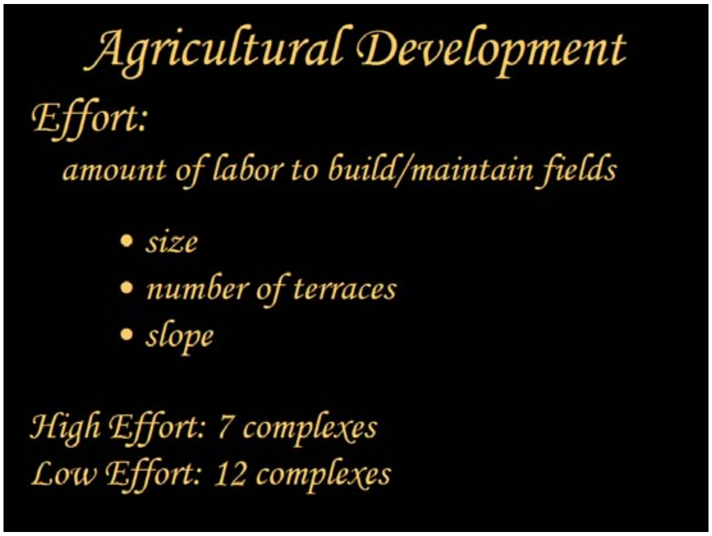
I got 19 AMS RC dates for the valley, and they range from 790 BP, or about AD 1200, to modern. So the earliest dates are at the bottom and they get more and more recent toward the top. Aside from the *lo‘i* systems, I dated several non-agricultural features, including two hearths, a habitation terrace near the coast, one of three ceremonial sites recorded for the valley, and the *ahupua‘a* territorial boundary wall.



The dates for the agricultural systems fall into three temporal units: the earliest is before AD 1400, the next is from AD 1400-1650, and the most recent is after AD 1650. These maps show the field complexes that would have been present in the valley during each time period. The systems in red are the new ones that were constructed during that temporal unit, with the values at the bottom showing their area. Clearly, the largest area of *lo'i* was constructed early on, relative to later expansion.

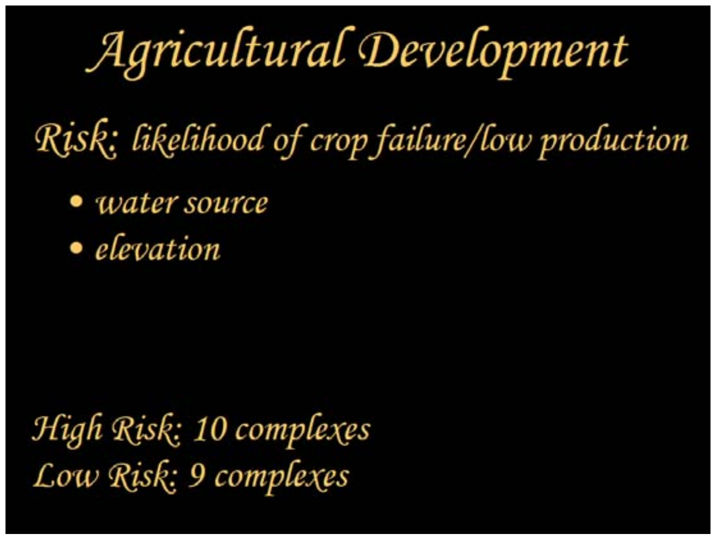
Agricultural Development

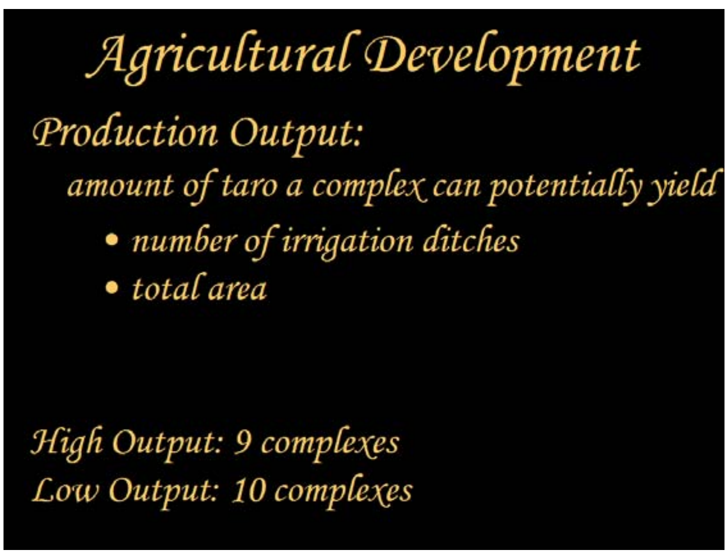
Effort, risk, and production output are the critical factors in the two models of agricultural development. The models link these three factors together, with the complexes requiring the greatest effort and involving the most risk also producing the most output.



Effort refers to the amount of labor it takes to build and maintain a field. Effort is reflected by the size of a *lo‘i* complex, the number of terraces within the complex, and slope of the system. Based on the values for these attributes, I devised two categories for effort: *High* and *Low*. 7 of the 19 complexes were classified as *High*, and 12 were *Low*.

Risk refers to the likelihood of crop failure or lower than expected production at different locales. Flooding is the greatest risk for irrigated agriculture in a wet valley such as Wailau, and this is directly affected by water source and elevation. Complexes fed by a side stream would be less prone to flooding than those watered by a main stream, while those located at lower elevations would be more subject to flooding than those at higher elevations. Two categories of risk were generated: *High* and *Low*, based on values for water source and elevation. 10 of the complexes were classified as *High* risk, and 9 were *Low*.





Production output refers to the amount of taro a complex can potentially yield. Number of irrigation ditches and total area affect crop yields, and were therefore used as indicators of production output. Two categories of output were generated: *High* and *Low*, with 9 complexes falling into the *High* yield group, and 10 classified as *Low*.

	High Output	*Low Output*
High Effort	*6*	*1*
Low Effort	*3*	*9*

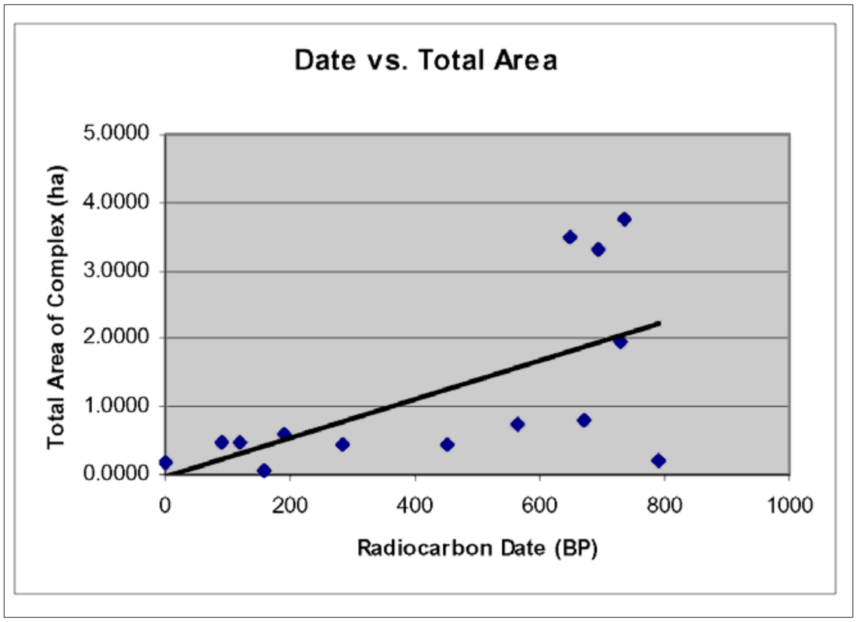
Effort was related to production output, with more *High* effort complexes categorized as *High* output, and more *Low* effort complexes falling into the *Low* output group. So large amounts of effort were invested in fields that could produce high yields.

	Temp Unit 1	*Temp Unit 2*	*Temp Unit 3*
High Effort	*6*	*0*	*0*
Low Effort	*1*	*2*	*5*

	Temp Unit 1	*Temp Unit 2*	*Temp Unit 3*
High Output	*6*	*0*	*1*
Low Output	*1*	*2*	*4*

Effort and production output showed the strongest relationship with the temporal units, with all of the dated *High* effort complexes falling within Temporal Unit 1, and all but one of the dated *Low* effort complexes falling within Temporal Units 2 or 3. Thus, the most effort was expended on the earliest systems, and less effort was invested in the complexes that were constructed later in time.

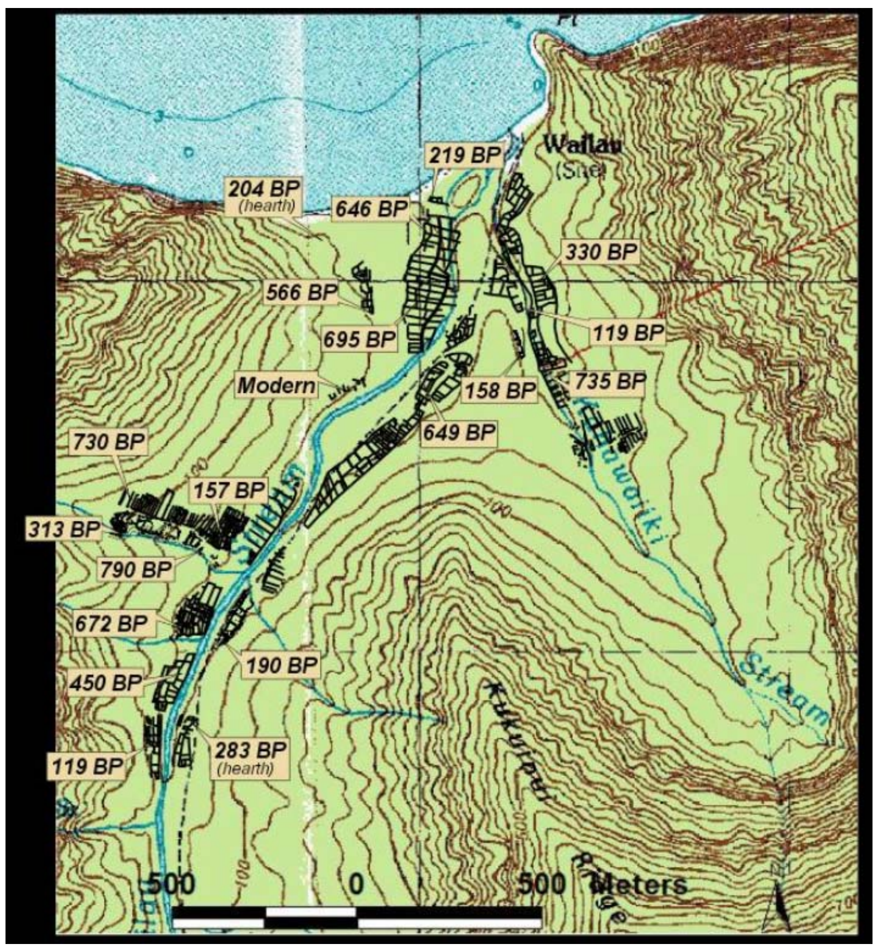
The temporal units are also clearly related to production output, with the *High* output complexes occurring earlier in time than those offering *Low* output. Note that the high yielding complexes were not necessarily built out completely during the first temporal unit in which they were established. Nevertheless, farmers were clearly assessing the likelihood of expansion of the terrace systems when they first selected areas for cultivation.



The raw data shows that total area corresponds well with the radiocarbon dates, with the largest field systems constructed earliest in time.

This analysis strongly suggests a pattern of agricultural development in which production output was a major consideration in initial *lo'i* construction, and large amounts of effort were invested in field systems that could produce high yields.

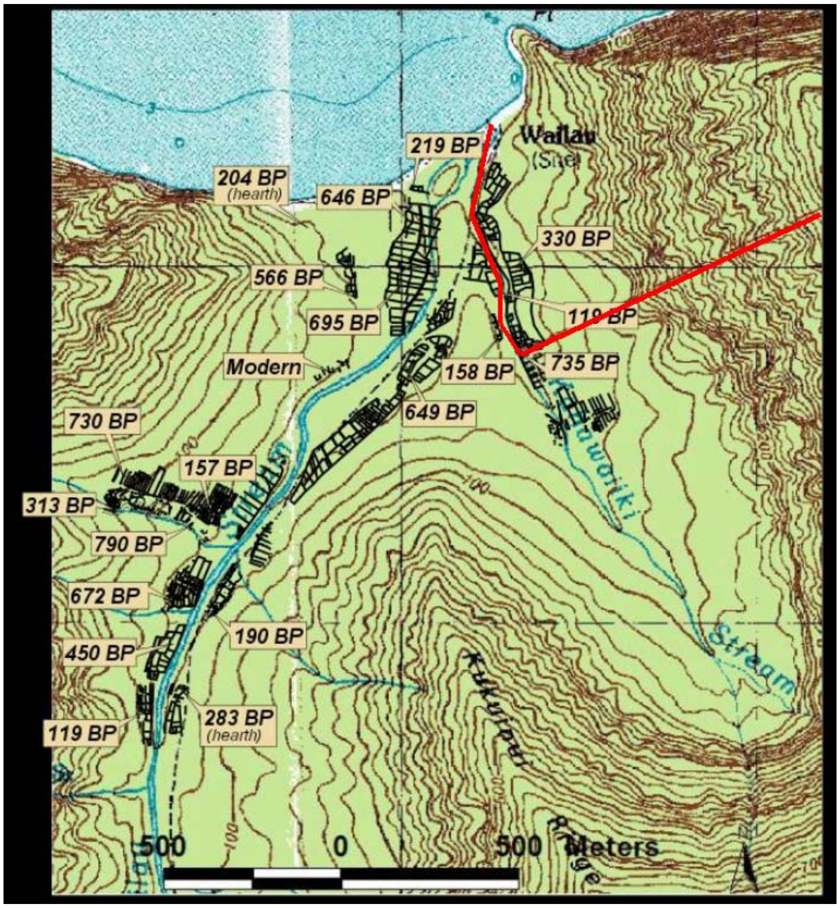
Conclusion



The goal of this study was to evaluate two models of agricultural development: one in which fields were extended directly inland from the coast to optimize production despite increasing effort and greater risk, and another contending that farmers first extended their fields to the valley slopes, which involved less risk and effort to construct and maintain terrace systems but produced lower crop yields. Effort and production output were determined to be the critical factors in the timing of *lo'i* construction in Wailau, which is consistent with the first model, although agricultural development was not as simple as the two models suggest. The high output systems were not all found on the valley bottoms as originally assumed. They were found throughout the valley – in the lowlands along the main streams, inland along the main streams, and on the valley slopes watered by secondary drainages. Farmers first took advantage of any area capable of supporting a high producing *lo‘i* system, regardless of risks of flooding or the amount of effort needed to construct a system or transport products to the coast.

This could be a tactic to spread out the risk, to place early fields in various locations so that if fields in one location are destroyed by flooding, those in other areas might still be viable. Spreading out the earliest fields might also be an attempt to gauge the potential of each location, to test how much taro can be produced and what risks are involved in the different areas.

After these large, high-yielding complexes were established, smaller *lo‘i* systems were built, until every cultivable tract of land was under production. These small complexes are good examples, in which a tiny bit of flat land along a stream was converted into a *lo‘i* system late in time.



Dating of non-agricultural features provided useful information as well. The *ahupua‘a* boundary was established early in time, when control of the large agricultural areas was of utmost importance. The ceremonial structure was constructed later, possibly at a time when population was growing and available space for cultivation was becoming increasingly limited. This would be a time when agricultural ritual would play a critical role in the life of the Wailau people.

In sum, the cultivation of irrigated fields began in the Thirteenth Century AD in Wailau. At this time, two distinct communities were established in the valley: Wailau Ahupuaʻa on the west and Hālawa Ahupuaʻa on the east. Extensive fields were constructed early on because of their potential to yield large amounts of taro. Soon the entire valley was under irrigated taro cultivation, and *loʻi* construction continued into the historic era, until unfavorable economic conditions and a devastating flood forced the last remaining farmers to abandon the valley. Today the fields of Wailau endure, remnants of a rich agricultural past whose story is just beginning to be told.

Thank You