

# MODELING PAST AND PRESENT IN THE EASTERN HIGHLANDS OF PAPUA NEW GUINEA: SUPPLEMENTAL MATERIAL

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## SUPPLEMENT 1: CONTACT HISTORY IN THE PROJECT AREA

For purposes of perspective in considering the simulations presented in this report and for understanding the increase in population growth in the historical period for the study area, it is useful to consider its contact history. In the pages that follow, we discuss contact history south of the Eastern Highland's major basins in terms of four remote regions (see Figure 2, main text): South Tairora from Suwaira to its boundary zone with Awa in the lower Lamari Valley; the Auyana basin and uplands from the Kratke Range near Nori'arunda in the north to Indona near Okapa in the South; Awa extending from the western edge of South Tairora to the Puburamba River on the southwestern edge of Auyana; and Fore. These areas were contacted and developed after World War II, well after the northern basins were explored and developed by missionaries, prospectors, and the Australian administration.

The historic period in this region begins in the late 1930s (approximately 1937–1938). At that time, a number of administration explorers passed through the area on their way to the Gulf Province, and steel tools became available to South Tairora in significant quantities through trade with Austronesian people who occupy the valley of the Waffa River, a tributary of the Markham River to the east more than 1400 meters below the Lamari Valley. Even in 1938, contact was transitory, and there is little evidence of its impact on the people of the Lamari

or their way of life. In the words of R.I. Skinner (1947–48):

Most of the area visited on this patrol had not been previously visited. Several parties had passed through the Awka-Kasokana, including Patrol Officer G. F. Neilsen, when proceeding to Papua during 1943 (approximately). Mr. K. F. Ubank also passed through this area on his way from Kainantu to Papua. Mr. F. H. Moy visited the Upper Lamari about 1937. ... C. R. Croft also visited the northern Head of the Lamari in 1937 or 1938 and the route of this patrol followed the same track as that taken by Croft when crossing from the Upper Lamari to the Nompia Area [North Tairora basin].

The Skinner patrol was the first postwar venture into the project area. Originating in Kainantu, it was routed through Kamano to Fore on the lower west side of the project area and proceeded south along the west bank of the Puburamba River, which it crossed at Ilesa near Tauna. The patrol visited Irakia for one day before continuing northeast to Baira in South Tairora and then to Nompia and Kainantu. Skinner's mission in Awa was to investigate reports of a salt source in or near Irakia. He found that reports of a salt cave or mine were false and that the people of Awa and South Tairora traded salt from Anga language speakers known widely in South Tairora and Awa as "Imaani." The Imaani occupy the southern side of the Aziana River, which joins the Lamari near Mobuta.

Boyd, who studied the economy and subsistence of the Irakia bounded complex in 1971–

1972 and subsequent revisits, was told by informants that when Skinner arrived, “adult men took refuge on the opposite side of a distant mountain” (Boyd 1975:43). Skinner (1947) reported that the men who remained were “nervous, although friendly” and the “Lamari River villages are under no degree of control”. Thereafter, only three government patrols visited Irakia between 1947 and 1953. According to Boyd, the first steel axe in Irakia was purchased from one of these patrols in 1949 or 1951 for the price of a large pig. The patrol officers in charge of these patrols also noted that “such infrequent contacts by the government were unlikely to extend the knowledge of, or adherence to, the Pax Australiana” (Boyd 1975:43). Beginning in 1953, the government intensified its patrols, and between September 1953 and September 1972, at least 13 patrols from Kainantu and Okapa either visited Irakia specifically or passed nearby on their way to Awa and Barua villages on the Aziana River. In June of 1954, a group of Irakia men visited the Okapa Patrol Post, a walk of approximately nine to ten hours, and one of their party stayed at the station to learn *Tok Pisin*, the New Guinea lingua franca. The first reasonably accurate census was taken in Irakia in June of 1963, with 242 individuals counted. While a number of aid posts providing very basic medical services were established in Tauna, Kaiwaina Number 2, and Abomotasa, they were rarely used by the Irakia and Tauna Awa, the Awa bounded complexes they were positioned to serve. Finally, in 1972, an aid post was established in Mobuta and was “highly recommended” by a number of Irakians who went for treatment of minor ailments (Boyd 1975).

By 1961, many new crops were introduced through trade from the west and by patrol officers who often distributed seeds, but few were actually used or eaten for lack of interest and fear that they were potentially dangerous (Boyd 1975:55). Coffee was introduced from the Fore village of Abomatasa in or about 1963. By 1972 some households had coffee gardens, with 5900 coffee trees in all states of maturity in Irakia; coffee is the only cash crop in Irakia. However, Boyd (1975:54) reported that a large variety of new food crops had arrived in Irakia and pre-

sumably other Awa bounded complexes within the memory of older informants in 1972. They all came to Awa through Tauna from Auyana over “traditional trade routes,” presumably through Norai’arunda from North Tairora and through Fore to the West from Kamano (Robbins 1982).

In 1963 the first group of young men was inducted into the Highlands Labour Scheme and marshalled in Goroka, where they were staged and used for town cleaning before being flown to the coast to work on plantations. Cole (pers. obs.) had occasion to meet many recruits from various parts of the highlands and observed that the first Awa group of about 40 individuals, many from Mobuta, were the most truculent and uncooperative of any similar Highlands Labour Scheme group he worked with in Goroka over a period of 21 months in 1962–1963.

In 1961 a Lutheran Kamano lay missionary was stationed in Tauna but left in 1962 when fighting broke out with the Iyona bounded complex, and all lay missionaries were withdrawn from the area by their supervisors (Boyd 1975:51). Since Boyd’s research in 1971–72, Irakia lost nearly half of its population to out-migration to northern population centers, the Papua New Guinea coast, and the outer islands. Efforts were made to bring these people back and were generally successful. The people of Irakia have recently abandoned pig husbandry and are replacing pork with imported sides of lamb.

The first non-administrative person to visit and study Irakia and Tauna was Pataki in 1962 and 1963, who studied the geography, social organization, and demography of the Awa for the University of Washington New Guinea Microevolution Project (Pataki-Schweizer 1980). The first to reside in Irakia was the anthropologist Phillip Newman, who did ethnological research there in 1964–1965. The SIL (Summer Institute of Linguistics) linguist Richard Loving studied the Awa of Mobuta and resided there intermittently from 1959 for many years, producing, among other works, a valuable paper on the use of bamboo irrigation pipes (1976). Cole (Watson and Cole 1977) visited Tauna, Irakia, and Mobuta in 1966 for site sur-

veys. The anthropologist David Boyd (1975, 2005) studied Irakia and the Awa in 1971–72 and on several visits thereafter through 1993, and the anthropologist David Hayano (1990) studied marriage and kinship in Tauna in 1969–1971. On a return trip in 1990, he reported a total lack of literacy in the Tauna, and by extension, other Awa bounded complexes. There were no schools, and the road from Okapa stopped far short of the nearest Awa settlements of Tauna and Irakia (Hayano 1990:155–159). In addition, missionary and government aid stations were farther away, and medical help for serious illness and injury required a rugged one to two days' walk to Okapa from both Tauna and Irakia bounded complexes, and much farther for Awa bounded complexes on the south side of the Lamari.

The steep topography of all approaches from the west and north have deprived Awa of vehicular roads. This has isolated Awa from important sources of influence in the past and may have deprived or delayed their adoption of the spade. Sorenson (1976) has recognized the importance of steel spades for the Fore in cultivating grasslands which are generally growing on Pleistocene clays overlain with deep thatch embedded in heavy clay topsoil. The administration required one day a week of labor using shovels for building and maintaining roads, which gradually provided improved contact with administrative and trade centers for Auyana and South Tairora speakers, and also acquainted villagers with the utility of the spade, thereby creating and spreading demand. Since most Awa sweet potato is grown in grassland, knowledge of the spade may have made sweet potato more attractive for a people who were growing taro and yam with digging sticks using a 10- to 20-year fallow cycle, thereby promoting the use and spread of this new cultigen.

In March of 1967, the villages of Tauna, Tawaina, and Irakia officially joined the Auyana Census Division and were represented by a local government councilor from Tawaina. At this point, they began to pay taxes. This has required their increased involvement in the monetary economy through labor contracts, coffee growing, working as household help in the larger

centers, and migration to locations outside of the highlands for employment.

We conclude this brief overview of contact history with a 'before' and 'after' story and assessment of contact made by some of Boyd's older male informants:

The older individuals, who vividly recall and take delight in telling stories about the 'time of fighting,' are the most emphatic in their support of the new conditions. During intensive periods of warfare, people made only a few gardens in relatively close proximity to the village, so food was often in short supply. The men took turns guarding the trails by day and night, and visits to friends and relatives in neighboring villages were made infrequently. Now there are many gardens and plenty of food, and people are free to go where they wish. As one informant put it, 'Before we were always afraid, but now we worry only about our children and our pigs' (Boyd 1975:59).

#### *Southern Tairora*

Following the 1947 Skinner patrol, which merely brushed the South Tairora bounded complex of Baira on its way to Nompia, the first postwar patrol into the northern end of South Tairora from Obura was led by Linsey in 1949. This patrol visited the Gadsup village of Akuna, and from there to Suwaira at the northern end of South Tairora and the headwaters of the Lamari River. In a subsequent patrol also in 1949, Linsey followed the eastern bank of the Lamari, through Himarata and across the southern heel of South Tairora's southeast corner past Ndumba, apparently without stopping, and then westward to Pinata and then south crossing over the mountains into the Aziana River Valley. He did not reach Awa on the first leg of this patrol, which was tasked with reaching the Papuan boarder. The patrol turned back for lack of food and possibly carriers and returned near Mobuta and then across the Lamari to Irakia; from there it went to Baira and north across mountains to Nompia and Kainantu. This was first post-war government patrol to pass through Ndumba lands in South Tairora on the South-east bank of the Lamari. From this first contact forward, the

extension of government control proceeded slowly, averaging approximately three visits per year and led by experienced patrol officers including Linsey and Brown. Many of these patrols were focused on the Anga people south of the Lamari and the establishment of a patrol station at Wonenara and further southeast to Menyama. Visits in the South Tairora bounded complexes of Ahea, To'okena, Anima, Ndumba (Habi'ina), Oraura, Konkonbira, and Pinata on the south side of the Lamari were cursory. Perhaps for this reason pacification was slow, and it was not until 1963 that Southern Tairora was considered pacified and unrestricted. At that time, a government patrol station was built in Obura and a Swiss Evangelical Brotherhood Mission was established in To'okena. Hays (1974:77–78) credits pre- and postnatal care provided by the Swiss mission with lowering the infant mortality rate in Ndumba by 1972. Presumably, other bounded complexes in the southernmost end of the Tairora territory were also impacted by this mission's presence.

In the late 1960s and early 1970s a clay road was extended into this area, and coffee buyers could reach parts of the middle Lamari River Valley in flatbed trucks, carrying shotguns for protection (Pataki-Schweizer pers. comm. 2017). The first ethnographers to study Ndumba (Habi'ina) in detail were the anthropologists Terence and Patricia Hays (Hays 1974; Hays and Hays 1982). Hays studied ethnobotany there, and his dissertation provides detail on gardening, forest species, sociocultural life, and population. In 1972, P. Hays counted 30,000 coffee trees at different stages of growth. This may also be an indicator of relative administrative influence and agricultural outreach from Aiyura for Ndumba, perhaps an exemplar for coffee growing in South Tairora generally and perhaps for Irakia, where Boyd reported 5900 trees planted in 1971–1972 in this bounded complex similar in size to Ndumba. Hays (1974:78) estimated the population growth rate from 1971 to 1972 to be as high as 3% for Ndumba. We have drawn on Pataki's figures and lowered the 1972 growth rate to 2.5% for Southern Tairora within the project area from Suwaira to the Tairora/Awa boundary zone. It is

noted also that many South Tairora bounded complexes were isolated and did not have access to medical services, including pre- and postnatal care.

### *Auyana*

The ethnographer Sterling Robbins, who studied the Auyana in 1962–63 and 1965, states that the first patrol to enter Auyana was in late 1949 or early 1950 (no citation given). There are two patrols by G. Linsey (1949–52a, b) that may have passed through Auyana during that time period (Kainantu, Vol. 2 No. 2 1949-50; Kainantu, Vol. 2 No. 8, 50-51, Southwest of Kainantu). Robbins was based in Tarendapa, a settlement or hamlet of the Asempla bounded complex, and his work centered on the "Auyana" bounded complex in his appellation, which we consider here as an exemplar of the collective Auyana language group and its bounded complexes as recorded by Pataki, who visited the Auyana language group in 1962 and 1963 and lived in Asempla (Amonanapa) settlement for a month (Pataki-Schweizer 1980:78–91). Cole (1996) surveyed Auyana in 1966 from the bounded complexes of Amaira to Asempla. Patrols in Auyana met no hostile opposition, and pacification occurred more rapidly in Auyana than in Awa and Southern Tairora. Robbins began field research in the Auyana bounded complex in 1962, and much of his resulting monograph focuses on warfare; he reports that he did not witness warfare in Auyana throughout his entire stay:

The government emphasized the cessation of fighting and since the time of the first government patrol came to their area in late 1949 or early 1950 (possibly 1947) there has been only one fight involving members of Auyana in which they killed someone (Robbins 1982:14).

Indigenous Christian evangelists arrived in 1957, and in 1960 a white Lutheran missionary and his wife came into the area to reside and lead conversions at Opoimpina. By 1962 only seven Auyana families remained active members, while other converted Auyanans did not continue their affiliation with the mission during Robbins's stay (Robbins 1982:14). Seventh-day

Adventist missionaries had also made scattered inroads to Auyana, including a family at the bounded complex of Asempa (Pataki-Schweizer 1980:83; pers. comm. 2020).

The close proximity of Auyana to the North Tairora and Kamano basins and an abundance of trade routes to both provided early access to steel tools, so that by 1950 every family owned or had access to a steel axe and knife (Robbins 1982:14). By 1962 some young men were unable to effectively use a stone adze, and by 1966 the manufacture of flaked stone tools was rapidly becoming a lost skill remembered only by the elderly (Cole pers. obs. 1966). Also, according to Robbins, “by 1962 every woman owned a dress” of foreign manufacture and most men wore belted “laplaps” (sarongs); in addition, a few had shorts and shirts by that time. Soap, matches, newspaper for cigarettes, stick tobacco, salt, and metal cooking pots were also common. Patrol officers had recruited laborers for the coast by 1953. In that year construction was started on the Okapa patrol station on the western edge of the Auyana basin within a few miles of Indona, the westernmost Auyana bounded complexes. The construction of a post for research on kuru (a neurodegenerative disease) in the late 1950s in Fore also promoted acculturative changes in this area.

The Okapa station was served by clay road from Kainantu and Goroka, and the Tarabo airstrip was within a few miles’ distance and also connected by road. Nevertheless, the steep mountain of the Kratke Range to the north from east to west of Auyana made road building and road maintenance difficult. Consequently, coffee was introduced later: in 1965 only five men were planting coffee in Auyana (Robbins 1982:15). This is not surprising since growers would have to walk two to three days to trade posts to sell their coffee beans at that time. This situation changed after 1954 as a rough and unreliable clay road was gradually extended by local labor from Okapa toward the northeast. It reached into the Kratke foothills over a period of years and eventually connected Auyana to Kainantu and Goroka through Okapa. In 1966 Cole’s survey party followed this road by foot from Amaira to Asempa and used the Kain-

antu/Okapa trunk road to position supplies at Okasa in preparation for site survey to Tauna, Irakia, and Mobuta. By 1974, a road loop from Kainantu through the North Tairora basin, over a pass in the Kratkes to Amaira and thence through Auyana to join the Okapa road, was available. However, roads did not extend into Awa, and Awa was still only accessible by a difficult foot path when Boyd made his most recent visit to Irakia in 2013 (Boyd pers. comm. 2019).

### *Conclusion*

For the purposes of this project, there are a few important points that bear repetition and emphasis. Bamboo pipeline irrigation systems were reported in Awa in Skinner’s first administrative patrol to Irakia and Tauna in 1947 and were seen and sketched by Loving (1976:526) near Mobuta from 1956 to 1972. They were described in Irakia by Boyd and reported in eastern Awa in patrol reports in 1956. The last report is from Boyd (pers. comm. 2020), who saw one made as a demonstration in 1993. Loving (1976) published a sketch of a remarkable example near Mobuta, and they were photographed in 1963 in Irakia by Pataki (Pataki-Schweizer 1980:103) and videotaped by Cole in 1966 between Mobuta and Tainoraba. We have no doubt that they were an essential part of the Awa material culture and were in use well into the late historic period. They are possibly still used in some outlying Awa bounded complexes. In many of the patrol reports between 1947 and 1956, the patrol officers have remarked on the scale and extent of bamboo irrigation. The scale varies with the witness and what they were able to observe, the range being from 0.5 to 3 miles (about 1 to 5 km) in length in single or double parallel lines, with no mention of more pipes per line (Figure 5b, main article). This may represent the late stage in the use of bamboo irrigation, since Loving’s report includes a drawing of four parallel lines, three of which carry two pipes and one with a single conduit diverging from a three-conduit trunk. This was recorded in or near Mobuta. Loving (1976:526) goes on to write:

Because it is taboo for women to step over the bamboo pipe, whenever the pipe crosses a trail it must be at some point where the trail drops so that women can easily walk under the bamboo with heavy loads on their heads. If this is not feasible, the bamboo pipe must be elevated on long poles where it crosses the trail. At places where the pipeline crosses a narrow gorge or natural depression very tall poles are erected. The builder must climb them in order to tie the pipe at the correct level. Usually the pipeline runs about one meter above ground level.

Of a subsequent patrol along the eastern side of the Lamari River into Ndumba and other South Tairora settlements as far west as Pinata near the eastern edge of Awa territory, Linsey (1949–52a) writes:

I reported in a previous patrol report (No. 7 of 48–49) that Taro becomes a more prominent feature of native agriculture as one proceeded south from Kainantu to Suwaira, this trend continues right down the eastern side of the Lamari, until, in the lower villages of the Azana Valley, taro becomes almost the sole item of food, with a little yam and no sweet potato. However, until the Azana Valley is reached, sweet potato is still the main food grown in conjunction with taro. A most interesting feature of native agricultural method in these taro areas is the system of irrigation. Even at Obura it is found in a modified form. But in the Azana villages it is always practiced. This consists of long lines of bamboo pipes which bring water down from high up on the mountain sides, in easy gradients to the gardens. These pipelines criss-cross the slopes and lead over spurs in every direction, sometimes in double lines and over a half mile in length with the bamboo pipes supported on stakes. Across the Lamari on the Western side [namely, Fore], sweet potato once again becomes the main crop and no pipelines are seen. There are huge groves of large bamboos in these taro growing areas, some of them many [? Units not legible] in extent and so there is always a plentiful supply of ‘pipes’.

As to the extent of these systems, as mentioned above, we have Linsey’s reports from his earliest patrols into South Tairora that a modified version of this system was found near Obura. Other reports say that they were common especially on the eastern bank of the upper Lamari and throughout Awa and the lower Aziana valley, and possibly into some parts of Fore on the western banks of the Lamari, as far north as Ilesa on the west side of the Puburamba River near Irakia. These reports confirm Hays’s (1974:54) report that older informants in Ndumba told him that bamboo irrigation for taro gardens were discontinued approximately twenty years prior to 1971–1972, when these interviews were conducted, i.e., the early 1950s. Brown also reported extensive pipelines (see photograph, Figure 5a, main article) on the eastern side of the Lamari south of Himarata, and Haberle (pers. comm. in Bourke *et al.* 2002) reported pipelines in Baira on the north side of the Lamari opposite Ndumba. As mentioned in the main article this system was then used for irrigation of coffee and possibly other crops (Haberle, pers. comm., 2020). This leaves little doubt that bamboo pipeline irrigation of gardens primarily planted in taro were once used from Obura through the Lamari Valley through Irakia, Tauna, Mobuta, eastern Fore, and Awa bounded complexes on the north side of the Aziana River, as witnessed by patrol officers (1947–1956) and anthropologists and recorded through interviews by Boyd in Irakia in 1972, by Pataki in Tauna and Irakia in 1963, and by Hays in Ndumba in 1972.

A second point made in many patrol reports has to do with the ratio of taro to sweet potato across the study area from Suwaira to Awa and the banks of the Aziana river. For example, Linsey in his 1949 report of a patrol from the Gadsup village of Akuna to Suwaira (see Figure 2, main article). observes the relative abundance of taro in the diet at Suwaira compared to Akuna and Gadsup, as follows:

Plots of yams and taro are planted by the Gadsup people, but much larger ones are to be found in the Suwaira area; in fact, it is not uncommon here to find a whole garden containing nothing but taro and yam, and it

seems that these make up a much larger portion of their diet than in the Akuna with the Gadsup people.

We know from Skinner's (1947) assessment that no sweet potato gardens were seen in Irakia and that taro is "the most important item in their diet although bananas were plentiful". Linsey (1949–52a) relates:

I have reported in a previous report (No 7 48-49) that taro became a more prominent feature of native agriculture as one proceeded south from Kainantu to Suwaira. This trend continues right down the Eastern side of the Lamari, until, in the lower villages of the Azana valley, taro becomes almost the sole item of food with a little yam and no sweet potato.

Also in a patrol report by Brown in 1953, we have a description of pipelines on the south side of the middle Lamari in South Tairora and well before reaching Pinata, where he turned south to cross the range to the Aziana. We also have two colored pictures from this patrol (see Figure 5a of the main article for one of them) showing pipelines extending for a considerable distance. Once again, these reports attest to the disappearance of taro irrigation in historical times in South Tairora and about 40 years later in the Awa bounded complexes of Irakia and Tauna (Brown 1952–54). In Irakia the last bamboo pipeline was constructed in 1993 to demonstrate to younger villagers how they were built and used in times past (Boyd, pers. comm. 2020).

There is a very detailed description of this form of irrigation in the Lamari Valley between Himarata to Mobuta by West, in which Brown (1955–56) also draws attention to the existence of large patches of bamboo in areas where pipelines are found. Also mentioned is the poor quality of the soil and the steep slopes and frequent burning of the short grassland and its effect on topsoil erosion:

The soil throughout this sector is extremely poor and consists almost entirely of rapidly eroding shales. The relatively small population ekes out a meager existence on scanty plateaus which are found a thousand feet and more above the course of the [Lamari] River. Here there is much evidence of how man has

wrestled with an unfavorable environment. For much of the year the valley is very dry and hot, and this reacts unfavorably on the excessively poor and porous soils. However, in an area otherwise practically devoid of timber, stands of bamboo frequently many acres in extent, were found along the watercourses. Through the ingenious use of these bamboos, the people convey water from streams to arable land up to three miles in extent but nevertheless water is piped along distances to it... Once the garden is reached, the water is conveyed to each and every Taro plant by movable sections or surface drains.

Finally, Hays reports from his field work in 1972 that taro, yam, and winged bean are a special triad of crops that require more care, are attended by more ritual, and are cultivated primarily by men, whereas sweet potato is easy to grow and store, is attended by little ritual, and is planted by women. Large taro gardens (50 ft x 200 ft, 15m x 60m) in particular were still planted in 1972 between 1615m and 1768m elevation, with only scattered planting at higher elevations, despite much of Ndumba gardening being at higher altitude where sweet potato was the major staple crop (Hays 1974:52). One must assume that more time was required to travel from settlement to taro garden as the forest line was pushed back and the distance between taro and sweet potato gardens lengthened. This situation would hasten the transition from taro to sweet potato since efficiency would decline as distance increased, especially prior to pacification when women required armed escorts to gardens.

The 1600 to 1800m altitude zone for taro is very similar to the altitude of taro gardens in Awa. According to Hays (1974:52), "Informants invariably stated that taro simply does not grow well at the higher elevations," and furthermore, "... higher sites which were for one reason or another marshy were considered capable of supporting a few taro plants, but nothing like the large patches nearer the river below." A little further on, Hays states: "Some taro gardens are as large as 200 by 50 feet in area, although most are slightly smaller". This can be compared to

Watson's (1983:39) account of taro in North Tairora:

Yet traditional taro is often specially planted in separate small beds, and in places chosen for moisture and fertility. These plantings are usually small numerous little pockets of from several to a score or two of taro cuttings [and] are tucked away into odd places, like the depression left by a disused latrine pit, a sunken grave at the forest margin, or a cul de sac where run-off and erosion from two sloping paths collect moisture and top soil.

The consistency and frequency of these reports suggest that observers have witnessed the disappearing traces of a previous subsistence regime once practiced throughout the study area and particularly in the upper, middle, and lower Lamari and Aziana Valleys. It seems reasonable to conclude that this adaptation consisted of intensive cultivation of taro and yam and possibly winged bean and depended on irrigation systems that employed bamboo pipelines in various configurations to bring water from upland creeks and springs to taro gardens at elevations of about 1600 to 1800m in elevation. It is likely that these systems compensated for the extreme topography of this area and its poor soils—possibly degraded through intensive farming over hundreds to thousands of years and by burning and possibly inadequate or poorly distributed rainfall. Apparently, this regime was in transition at the time of contact as the economy shifted from a taro and yam base to sweet potato. The transition also apparently occurred along a time-space gradient from the upper Lamari headwaters to Awa. If the date of approximately 300 years BP for the introduction of sweet potato into the major valleys is correct, we can estimate that there was some delay in the movement of this new crop into more remote areas, just as there have been delays in the movement of the new economy, markets, and other entailments of Western contact, including pacification, roads, steel tools, medical stations, missions, and schools.

In 1972, the conversion to sweet potato was about 40% sweet potato to 60% taro in Irakia, while in the Aziana valley the sweet potato/taro ratio was apparently much lower, with sweet

potato reported absent according to some early patrol reports. From this we infer that sweet potato arrived later or was adopted more slowly or some combination of both in those Awa bounded complexes, and perhaps in Barua villages along the Aziana. This irrigated taro and yam regime may have extended into South Fore as well, although the instances reported there of bamboo irrigation may have been in imitation of the eastern systems, though it is equally possible that this adaption was practiced very widely throughout the Eastern Highlands and has disappeared, leaving no trace since the introduction of sweet potato. This would not be surprising since the pipeline systems would decay within years: witness the complete disappearance of physical evidence of such structures in Ndumba between Brown's report in 1953 and Hays's observation in 1972. In addition, while Cole and Pataki saw active pipelines in Awa, they did not see any remnants of bamboo pipelines in 1963 or 1966, respectively, when they visited South Tairora, and sightings are absent from patrol reports in South Tairora by 1958 as well.

A scenario such as this is not unreasonable or surprising, given the isolation of the Lamari Valley populations and their resistance to the impacts of European contact. With all of the technical and organizational advantages available to missions, prospectors, miners, and administrative personnel—radio, writing, firearms, aircraft, enormous supplies of shell-wealth and salt, and Papuan constabularies—the northern basins comparably were under administrative control for 20 years, and in some cases in Kafe, Kamano, and Northern Tairora 30 years earlier, whereas Southern Tairora and Awa were declared unrestricted as late as 1963.

## SUPPLEMENT 2: ARCHAEOLOGICAL SEQUENCES IN THE STUDY AREA

Archaeological research in the project area has revealed a continuous lithic sequence with directional change over time and space, based on frequencies of 24 stone tool types and a functional analysis of tools and sites in the project area.



### *Mamu Phase (~21,000 to ~4200 CalBP)*

The sequence begins with the Mamu phase of the Nanoway tradition (~21,000 to ~4200 CalBP). The Mamu phase is most clearly represented at the NFX open site in the upper Lamari Valley and the lower levels of Batari and Aibura rockshelters in the Lamari watershed between North and South Tairora (Figure 1 in main article). This early phase is characterized by lithic assemblages containing a high proportion of highly reduced asymmetrical (often stepped) edges, small tool and debris size (less than 200 gm), and the absence of tools suited for chopping and the extraction of wood, a resource of primary importance for subsistence throughout the New Guinea Highlands. Large flake and pebble tools (above 200 gm) and polished adzes are absent.

### *Late Mamu to Tentika Transition phase (~3960 BP to ~1000 BP)*

In the project area, the Mamu phase is succeeded by a transition that occurs at different times in different locations. At NFB, north of the Lamari headwaters, this transition begins as early as ~3960 BP. At Aibura (NAE) and Batari (NBY), the transition is later. While the transition dates at these sites are inexact, the change is estimated to have occurred between ~3500 and ~1000 BP (Watson and Cole 1977; Cole 1996). It is marked by the appearance of a wider range of tools and materials, an increase in ground and polished stone, a broader range of modes of production, and at NFB, the appearance of ceramics in significant quantities (ca. 3200 BP). This transitional Mamu phase also occurs at the Kafiavana rock shelter (NBZ) about 50 km northwest of the project area, where it begins at ~11,000 BP, ends at a horizon dated to ~4600 BP, and lacks ceramics entirely. A recent date may push the beginning of this phase back to ~15,000 BP (Huff, pers. comm. 2019). The stone-tool assemblage from Kafiavana contains a Mamu component of small flake stone tools with a high ratio of stepped flaked edges to edges without step flaking. This component resembles Mamu lithics in the project area. However, at Kafiavana these small “maintenance” tools are accompanied by a more

robust component of larger worked and used flake tools (above 290 gm), polished axe-adze blades, hammers, anvils, and large flakes, the latter possibly adze blanks or raw materials cached for later reduction (Huff 2016). The greater range of size, form, and function of this component has been interpreted as evidence of base camps at or near the site as compared to remote work camps in the Mamu phase at Aibura, Batari, and NFX (Cole 1996).

Noting dates as early as ~9400 BP to ~7000 BP for taro, yam, and banana horticulture in Kuk and other swamp sites in the Western Highlands (Denham 2003), these extractive tools suggest that a shift toward a similar sedentary subsistence may have started earlier in the vicinity of Kafiavana than in the project area. This interpretation is based on a single site and presumes a diffusion of horticultural technology from the West. Considering the relative proximity of Kafiavana to the Kuk and Manim sites (142 km), diffusion might be expected. The presence of marine shell at Kafiavana in levels VII and IX attest to trade before 6,000 BP with the coast, which lies at comparable geodesic distances: north toward Madang (88 km) or east (169 km) to Lae.

### *Tentika phase (~1000 BP–1968 CE, ethnographic present at end of project)*

The end date for the transitional Mamu phase is not clear because of gaps in dating and discontinuities in the stratigraphic record. At Kafiavana there is a considerable gap in dates and cultural deposit between 4690 BP and 180 BP; at NFB, there is a similar gap between 2060 BP and 185 BP. In Aibura there is a smaller gap at approximately 1000 years ago, possibly after its use for human interment. Batari was abandoned after 850 BP, a date which also marks the end of the transitional Mamu deposit (White 1972). In the project area, the Tentika phase emerges within these gaps in the last 1000 years. There are dates from two of four excavated open sites of ~290 BP from MGM in North Tairora and ~180 BP from NFC, both in North Tairora (Watson and Cole 1977). Tentika sites are defined by a relatively to extremely low ratio of stepped asymmetrical edges to un-

stepped flake tools with symmetrical edges. Tentika sites also contain at least some of the following: house remains, cooking pits, pottery, axe/adze blades, obsidian, whetstones, fences, pig enclosures, house remains, latrines, post-contact artifacts, rectangular hearths, and large earthworks. With the exception of large earthworks, these artifacts and features reflect the material culture of the project area immediately prior to contact with the west. The Tentika levels at Aibura and Kafiavana mirror these changes and include marine shell ornaments, pig bones, and ground and polished stone tools and

ornaments. The step flake mode of flake tool reduction disappears during this phase and could not be demonstrated, reproduced, or remembered by elders in the project area during the mid-1960s. Eighteen of the 66 open sites located by Cole (which included the study area, all of North Tairora and a small area in Fore) have been formally identified as Tentika. Subtracting the twelve Mamu sites, there are 36 sites with insufficient tool counts for typological operations, yet most of these have evidence clearly placing them within the time period of the Tentika phase.

### SUPPLEMENT 3: METHODOLOGY

**Table 1a. Irakia productivity, taro/yam vs. sweet potato 1971–72 (from Boyd 1975).**

<b>Garden type</b>	<b>Taro/yam productivity kg/hectare</b>	<b>Sweet potato productivity kg/hectare</b>
Forest taro/yam	4492*	
Irrigates forest	16,950	
Irrigates forest	15,000	
Irrigated grassland	13,411	
Forest sweet potato		17,081
Tilled grassland		8540
Untilled grassland		11,444
Peanut		
Sugar cane		
<b>Totals</b>	<b>45,361</b>	<b>37,065</b>
<b>Mean</b>	<b>15,120</b>	<b>12,355</b>

\* The figure for forest taro/yam gardens (4492) is lower because these gardens grew non-tuberous crops that were not included. It is therefore excluded from the mean (Table 1b below, same column).

**Table 1b. Irakia 1971–72 garden area by type in hectares (from Boyd 1975).**

<b>Garden types</b>	<b>1971–72 Area ha Taro/yam</b>	<b>1971–72 Area ha Sweet potato</b>	<b>1971–72 Area ha Non-tuberous</b>	<b>Total Area Hectares</b>
Forest taro/yam	2.6136			42.3
Irrigates forest	1.3540			269.2
Irrigates forest	0.0505			119.5
Irrigated grassland	0.5594			
Forest sweet potato		1.4728		
Tilled grassland		1.2712		
Untilled grassland		0.1452		
Peanut			0.3691	
Sugar cane			0.0155	
<b>Total Area Ipomoean</b>	<b>4.5775</b>	<b>2.8892</b>	<b>0.3846</b>	<b>7.8513</b>
<b>Total Area Pre-Ipomoean</b>	<b>4.5775</b>	<b>1.9434</b>	<b>0.3846</b>	<b>6.9055</b>

*Note: These figures are used in the calculations below; they adjust the area cleared per production unit for (1) sweet potato fed to pigs, (2) productivity differences, and (3) differences in caloric yield.*

### *Adjustment for Sweet Potato fed to Pigs*

From Boyd's ethnography, 20% of the sweet potato grown in Irakia in 1971–72 was fed to pigs. Unlike sweet potato, yam and taro must be cooked to produce adequate fodder for pigs. Furthermore, there is the disdainful and repeated cultural rejoinder, "Sweet potato is food for pigs," quoted as a typical Irakia attitude at that time. It is unlikely that prized and ritualized taro and yam would be so desecrated and wasted as to be grown as pig food. Consequently, we estimate pig husbandry to be less intense and herds to be much smaller in the pre-ipomoean past with more dependence on semi-feral grazing supplemented with food scraps used to bond otherwise feral pigs to humans and their habitats.

Our first revision reduces the amount of sweet potato grown in 1971–72 by 20% to estimate more accurately the amount intended for human consumption and recalculates the 1971–72 sweet potato garden area to match that reduction. This was accomplished with the following equation, where P = productivity of sweet potato, A1 is the total area in hectares for sweet potato, and A2 is the calculated "adjusted" garden area in hectares after the 20% reduction in required output:

$$\frac{0.80P1}{P1} = \frac{A2}{A1}$$
$$\frac{29,652}{37,065} = \frac{A2}{2.8892}$$

$$A2 = 29,652 \times 2.8892 / 39,065$$

$$A2 = 2.311 \text{ ha}$$

This output (an area 152m by 152m) becomes the input for the second equation below, which adjusts for the difference in productivity between sweet potato and taro/yam gardens.

### *Adjustment for Productivity Difference*

While sweet potato carried many advantages for a highland economy, including an ability to thrive at higher altitudes, preference for drier soil, and a shorter term from planting to harvest, its productivity (P2) is lower than the productivity of taro and yam (P1). This difference is addressed in the second adjustment, which uses

the productivity difference over the productivity of taro yam gardens to reduce the area of taro and yam gardens required to compensate for the absence of sweet potato.

$$\frac{P1-P2}{P1} = \frac{45,361-37,065}{45,361} = \frac{8,296}{45,361} = 0.183$$

Inverting this result by subtracting it from one gives

$$1 - 0.183 = 0.817, \text{ where}$$

$0.817 \times 2.311 \text{ ha} = 1.889 \text{ ha}$ , the adjusted area (137.4m by 137.4m).

### *Adjustment for Energy Potential*

The above result was then adjusted to reflect a slightly higher energy yield in Kcals for cooked sweet potato over a cooked yam taro mix of 80% taro and 20% yam, approximating the Irakia mix in 1971–72.

$$\frac{\text{Kcal sweet potato}}{\text{Kcal taro yam mix}} = 1.029, \text{ and}$$

$$1.029 \times 1.889 = 1.943 \text{ ha (139.4m by 139.4m),}$$

the final taro/yam garden area to replace sweet potato yield. This output was then used to recalculate the total Irakia garden area required to support the sample population:

4.578 ha (original taro yam garden measurement and other crops)

+1.943 ha (area to replace sweet potato after adjustments)

+0.384 ha (area for peanut and sugar cane)

6.905 ha (or 262.8m by 262.8m) of garden area to support an Irakia population sample of 117.

### *Calculation of the Land-Use Parameter for the pre-*Ipomoean* model*

Boyd also measured the Irakia garden work force in terms of "production units" (PU), e.g., 69.8 PU for the sample population of 117. From our calculations, this means that each production unit must cultivate 989 m<sup>2</sup> (an area 31.4m by 31.4m) of land in order to produce the nutritional requirement for the sample population. In addition, the number of PUs in a given popula-

tion can be calculated using the ratio  $69.9/117 = 59.6\%$ , where  $6.9055 \text{ ha} = 69,055 \text{ m}^2$ ;

$\frac{69,055}{69.8} = 989.32 \text{ m}^2/\text{PU}$  and  $\frac{69.8}{117} = 59.6\%$  of any simulated pre-ipomoean population (i.e., the percentage for PUs).

Note: the topographic area measurements of Irakia gardens made by Boyd do not include fallows between gardens. We estimate this fallow to be approximately 15–25% of used garden area. Boyd's (1975) measurements are topographic. The measurements calculated from Landsat imagery used for modeling parameters in this article are planar. They underestimate topographic areas by an estimated 20–25% due to slope. These two sources of inaccuracy cancel each other to a significant extent, yet the exact error is necessarily unknown: while a more ambitious topographic GIS approach would correct for slopes, there is insufficient data to more accurately estimate unused garden fallows.

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