LOCAL HUMAN-SWEET POTATO-PIG SYSTEMS CHARACTERIZATION AND RESEARCH IN IRIAN JAYA, INDONESIA
With Limited Reference to Papua New Guinea

A Secondary Literature Review

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"Poverty Alleviation and Food Security through Improving the Sweetpotato-Pig Systems in Indonesia and Vietnam"

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0. Executive Summary

This report is a review of some of the English-language literature relevant to understanding, and improving, the sweet potato-pig systems primarily in the Baliem Valley of Irian Jaya Province, Indonesia. While there is a substantial body of literature on both sweet potatoes and pigs for the island of New Guinea, most of the literature deals with either sweet potatoes or with pigs separately, and much of the literature is based specifically on research conducted in Papua New Guinea. There is a gap in addressing the integrated nature of the sweet potato-pig livelihood systems, particularly those present in Irian Jaya. This review is an attempt to bring together the research literature on these two components of agriculture and animal husbandry in the lives of the native peoples of Irian Jaya. In order to enhance overall understanding, a considerable number of reports and publications from work in Papua New Guinea have been included. One of the important considerations of this review is to highlight the implications for research to be undertaken by the International Potato Center (CIP) and its partner institutions and individuals under the project entitled *Poverty Alleviation and Food Security through Improving the Sweetpotato-Pig Systems in Indonesia and Vietnam.* This project will run from January 2001 to December 2003, with financial support from the Australian Council for International Agricultural Research (ACIAR).

Archeological and paleontological evidence suggests people have lived in the New Guinea highlands for as many as 30,000 years. Furthermore, they have practiced agriculture for about 2,000 years, raised and bred pigs from Asia for at least 1,000 years, but cultivated sweet potatoes from South America for only the past 300 years or so. A picture emerges in this century of indigenous peoples with Stone Age implements almost exclusively cultivating a single crop--sweet potatoes-- and raising a singular animal--pigs. The former constitutes the staple diet of both humans and pigs, while the latter constitutes the basis and currency of complex social exchange networks. Some of the most interesting and useful information in English about humans, sweet potatoes and pigs in present-day Irian Jaya is contained in various anthropological and geographical publications dating from the 1960s. While this fascinating body of literature provides a solid, yet diverse, data baseline for understanding the socio-cultural, political, bio-physical and agro-pastoral contexts, the past 40 years has witnessed profound and considerable changes in these contexts. Therefore, some if not much of what is reported in the earlier literature may no longer accurately describe the present-day situation. Bureaucratic governmental administration, transmigration from other Indonesian provinces, Islamic and Christian religions, new crops and livestock, and commercial goods and markets were only introduced into the Baliem valley in the latter half of the 20th Century. The present project represents a remarkable and unique opportunity to contribute to identification and understanding of the effect of these relatively recent changes in socio-cultural, political, economic, agronomic and animal husbandry spheres.

In the Baliem Valley, sweet potatoes (*Ipomoea batatas*), known locally as *hipere,* are cultivated on both the valley floor and the upland slopes surrounding the valley. Among the Dani people in this area, cultivation on the wet valley floor traditionally utilizes a complex system of semi-permanent raised beds, mounds and canals known locally as *wen-tinak*. An important function of the ditches, in addition to

drainage, is to serve as a source of fertilization as mud and organic matter from the canals is applied onto sweet potato mounds. Up to 200 cultivars are planted in this system, with 10-40 varieties planted in any particular bed. On the upland slopes, cultivation systems known locally as *yawu*, do not generally employ mounds, though there may be some terracing, and fewer cultivars are planted. Soil fertility is maintained through regular land rotation and fallowing, often involving nitrogen-fixing *Casuarina* trees, along with manure from grazing pigs. Dani men provide some of the labor for land clearing, soil turning and fence building, but the women also provide labor for these tasks and do most of the planting, tending, weeding and harvesting of roots and vines. Roots are harvested as needed and generally "stored" in the ground. Subsistence yields reported vary from 2-50 t/ha, with most ranging from 5-25 t/ha.

At least 500 sweet potato cultivars have been collected and documented from the Baliem Valley, and there are likely over 1,000 local varieties, with 28-81 in any single area or community. The Dani exhibit a wealth of indigenous knowledge concerning characterization and utilization of local varieties, and the Dani cultivar lexicon is formidable. Cultivars are often classified locally by skin and/or flesh color, as well as their suitability for human and/or pig food. Most varieties are low in protein, less than 3% of the dry weight, but sweet potato still accounts for about 75% of protein intake, and 90% or more of total caloric intake. Nevertheless, severe food shortages are only periodic events, mostly tied to weather-related calamities. Sweet potato is subject to some pests and diseases, like weevils, viruses, and bacteria, but the most serious risk to sweet potatoes is frost, especially above 2,700m elevation. Extensive and prolonged droughts have also been recorded periodically in Irian Jaya, and floods along the main river courses have occasionally had disastrous effects, though their occurrence and impact in the Baliem Valley is not well documented.

The island of New Guinea is the pig center of the world, with pigs enjoying a protected and almost revered status among the Dani because of their socio-economic importance. The Dani consider pigs, which equate to wealth and social importance, the most important living creature besides people. Many cultural interactions involve payment of pigs, often in the form of reciprocal obligations. Traditionally, most pigs are saved for ceremonial purposes, and are tended primarily by women and children. Great pig festivals, involving the mass slaughter of pigs and the use of sacral objects, including sweet potato tubers, take place about once every five years, and pig jawbones are maintained in the men's traditional houses (*pilamo*) as the recorded history of these events.

The management system for pig production is extensive, with village pigs (*Sus scrofa papuensis)*, known locally as *wam*, often let out in the morning to graze forest areas and fallow fields, and penned at night, with feeding of sweet potatoes, either cooked or uncooked. Local pigs are also distinguished by color, and some European breeds have been introduced. Most accounts indicate low growth potential of village pigs, and pigs make take two to three years or more to reach maximum size. A number of indigenous practices and rituals are associated with attempts to enhance pig growth rate. Though sweet potato tubers and vines account for most of the feed, pigs supplement this through their own foraging, apparently obtaining additional protein from consumption of soil fauna, particularly earthworms. Unlike in parts of Papua New Guinea, no large-scale commercial piggeries are sustained in the Baliem Valley. Local pigs are affected by a variety of pathogens, including the bacteria that can cause "pig-bel" disease in humans, as well as the pig tapeworm that can be transmitted to humans through improperly cooked pork, which can result in cysticerosis. More generally, the chronic ailment of pigs is open sores on the skin.

Despite the prevalence and importance of both sweet potatoes and pigs to the Irianese in general, and particularly the Dani, and the pervasive relationships between the people, the plant and the animal, very few have pursued a systems approach to determine associated research priorities. There is also a general lack of experimental work conducted on-farm, with full participation of local farmers; therefore, some reported research may be of little direct relevance to actual farm conditions and potentials. Moreover, there has been a tendency in the literature to assume regional generalizations, thus the present project must cautiously evaluate conditions and conclusions from other geographical and cultural areas of New Guinea for relevance to the local situation.

The review of relevant literature suggests a number of considerations and implications for integrated systems research in the Baliem Valley. Lack of comprehension of local language and culture can present difficulties to outsiders, and require the close and constant collaboration of local Dani people on the research team. The project could complement existing efforts to understand Dani-language terminology by assembling a farming systems lexicon and English equivalents to help avoid misunderstandings due to language. Women are the main repositories of knowledge and expertise on both sweet potatoes and pigs, and thus warrant particular attention and participation in the research process. Careful and precise documentation of the present-day socio-cultural and economic context of sweet potato cultivation and pig husbandry could provide an invaluable new set of baseline data that might help locals and outsiders alike to assess the changes of the past 40 years. Therefore, the project should strive, wherever possible, to obtain data comparable to those already obtain from Papua New Guinea and elsewhere in Irian Jaya.

Knowledge of sweet potatoes and pigs in traditional farming and husbandry systems is still inadequate, especially crop and human responses to environmental stress such as drought and excessive moisture. Further evaluation of existing sweet potato cultivars, and breeding of new ones, is needed, as are data on pest and disease problems, and their economic significance, in both sweet potatoes and pigs. However, the conservation of local varieties and farming systems should be thoroughly considered before undertaking wide-scale introduction of improved varieties. Farmers should be involved at an early stage in evaluation of traditional and introduced germplasm and technologies, and farmers' preferences and desires given due consideration. Integration of sweet potato into programs for the development of secondary crops could be improved, as could integration of aspects of sweet potato cultivation and pig husbandry into the training of local agricultural extensionists. There is little, if any, existing information on the cash crop status of sweet potatoes and the commercial status of pigs in the Baliem Valley, or on the response of sweet potatoes to fertilization and the response of pigs to balanced diets and intensive husbandry. These are both areas where the project can add greatly to the state of knowledge regarding production, consumption and marketing of sweet potatoes and pigs. Furthermore, the extent to which Dani produce and consume rice, as both supplement and replacement for sweet potatoes, is an interesting question to bear in mind. The contribution to, and variation in, sweet potato--both tubers and vines--to the modern Dani diet likewise warrants further investigation.

There is considerable scope for improvement and development of pig management systems, including the use of sweet potato for pig feed, but this will require an understanding of the changes taking place in the role of pigs in villages, and the resulting human-food-pig relationships. Some gains in pig productivity may be possible through increasing the genetic potential by crossbreeding, reducing mortality through better health care, and improving management methods. Intensification of root crop production, increased development and availability of other food sources, and development of storage systems to ensure continuity of supply may result in improvements in pig food availability. Adoption of means of storing and preserving pig meat may also provide a pathway for improved food security. Investigation into modification of existing free-ranging pig management systems, including a rotational system of paddocks planted to sweet potato for rooting by pigs, also merit consideration. Local constraints to the development of commercial pig farming should be investigated, and there appears to be virtually no information available in the literature regarding the commercial marketing of pork in the Baliem Valley. It will be important for the project to begin to diagram marketing chains from production to consumption.

Some studies have alluded to the linkages between local inhabitants, their sweet potatoes and agriculture more generally, and their animal husbandry, specifically pigs. However, there is virtually no data on territorial land organization in the Baliem valley, in the pattern of "drainage districts,' and yet this information could provide the basis for deeper understanding of these linkages and relationships. Moreover, there remains a need to examine closely the available information on climate and weather in order to better understand the limiting conditions, if any, to sweet potato in the Baliem Valley. There is a need for better knowledge of native soil factors influencing potential yield in areas of subsistence agriculture where artificial fertilizer is expensive and rarely available. Basic demographic data on both human and pig populations, as well as data on sweet potato production and consumption, would help to shed light on fundamental issues such as the carrying capacity among the Dani of the Baliem Valley. Existing data are regarded with caution, yet reliable data will be necessary to predict and prevent future food shortages. Since local farming systems rely heavily on female labor, depletion of male labor for off-farm income generation may provide some resilience in the system to socio-economic change and reduce vulnerability to food shortages in some areas. Nevertheless, investigation of traditional survival strategies during times of crisis like the 1997/98 ENSO drought-related food shortage may begin to reveal some answers to questions about carrying capacity and nutritional adequacy. Integrated systems modifications, such as storage of sweet potatoes and pork, cover cropping and use of green manures, and technologies that reduce the labor burden of women all warrant attention by the present project.

1. Introduction

A comprehensive understanding of the complex system of humans-sweet potatoes-pigs in Irian Jaya is a necessary basis for designing relevant action research to improve the efficiency of the system. Such a comprehensive assessment of the humans-sweet potatoes-pigs system will provide the socio-cultural and economic context that any action research aimed at improving the system must take into consideration in the design of locally appropriate and relevant trials. This review of secondary literature is a contribution to the assessment, characterization and analysis of existing humans-sweet potatoes-pigs production systems within the overall household economy, and a partial attempt to understand the types of systems, their relative importance and their major constraints in New Guinea, primarily in Irian Jaya.

In regards to the considerable research efforts that have preceded the present project, the remarks of long-time New Guinea human geographer Harold Brookfield (1991:205) bear repeating:

> *The first task, in a region only opened to research from the 1950s onward, was to establish a basic ethnography among subsistence farmers who used only tools of wood and stone and were only newly in possession of steel tools, and only recently brought under administrative control. The major changes of monetization, taxation, and novel forms of political control, the onset of substantial migration, the adoption of cash crops, significant access to health and education services, the beginnings of urbanization, modern forms of class structure and elitism--all these were taking place simultaneously with the first generation of research. While anthropologists and human geographers were describing, interpreting, and classifying a set of varied, similar yet contrasted, small societies as they found them, and as they were thought to have been before colonization, they were also swiftly taken up with questions of social and economic change.*

The present literature review is therefore also an attempt to highlight some of the findings of this "first generation of research" in relation to sweet potatoes, pigs, and humans in New Guinea, particularly in the western half of the island. It is hoped that this synopsis will provide project personnel with somewhat of a baseline with which to compare contemporary manifestations of the sweet potato-pig-human continuum. At the same time, the review is also an attempt to highlight the major findings of subsequent generations of research on sweet potato agronomy, pig husbandry, human health and nutrition, and other related topics. Although the intention of this review is to focus on research results from West New Guinea (present day Irian Jaya), the corpus of agricultural research is largely from work done in Papua New Guinea (PNG). Initial research in the highlands of Irian Jaya during the Dutch colonial period prior to 1962 was limited, and no major research by foreigners was thereafter permitted (Brookfield, 1991:207), until well into the 1990s.

Nevertheless, there are good reasons to consider that much of the research from PNG has, with due caution, some applicability to the situation and conditions in Irian Jaya. Brookfield (1991:207) notes that there are many similarities and few apparent differences in the course of events and resulting patterns in the central highlands of

Irian Jaya and those in PNG, yet there has been little comparative analysis. Even some of the major hypotheses regarding land degradation in parts of the highlands can likely be applied to both PNG and Irian Jaya, where similar sets of conditions exist. An example of this is the hypothesis advanced by Allen and Crittenden (1987; cited in Brookfield, 1989:206-7) that sought to explain land degradation as a result of a constantly escalating political economy based on competitive prestation of pigs fed on sweet potatoes. But Brookfield (1991:206-7) acknowledges that the tendency to argue using data from only a part of the highlands is a problem with the work of the first generation, as well as present studies.

This caveat pertains to both bio-physical and socio-economic aspects of agricultural systems in the two regions. The highland region of Irian Jaya, significantly, is not covered by successive showers of volcanic ash, as is that of PNG. This has considerable agronomic and ecological importance, and it may be that the intensive land-management systems in Irian Jaya are a response to the greater sensitivity of these highland soils to degradation and erosion (Brookfield, 1991:207). Furthermore, the highland areas of the now independent nation of Papua New Guinea were brought under colonial government control by the 1950s, while the western highlands of the Indonesian province of Irian Jaya were still only partly under the control of the colonial Dutch government at the time of the handover to Indonesia in the 1960s. Brookfield (1991:203) notes that economic development reflects this differential history, for while there is major development of cash cropping and an extensive road network in PNG, the highlands of Irian Jaya are still only weakly integrated into the rest of the Indonesian nation. With deference to behavioral and structural forms of explanation, Brookfield (1991:207) nonetheless believes that ecological differences should form an important element in comparative interpretation of human history, agro-technology, and social organization. He also believes that this will occur once investigations in Irian Jaya like the present project reflect the findings of research in the highlands of PNG. Yet he warns that much is still unexplored, and controversy and uncertainty remain, "while the drama of social and political change continuously makes all earlier prognostications obsolete" (Brookfield, 1991:206).

Ultimately, the present project purports to undertake applied research to further human development goals. Oomen (1961:332) has argued that development often implies increasing per capita income, but that in Irian Jaya the subsistence economy will be of prime importance for a long time. The former emphasizes cash crops, the latter the improvement of the quality of food crops and animal products. The only short cut to improvement, according to Oomen, seems to be upgrading highlanders' staff of life, the sweet potato. The past forty years does appear to have born witness to the accuracy of Oomen's prediction. More recently, Randa (1994) has also argued that the best approach in the implementation of community development in Irian Jaya is through development of the agricultural sector, specifically in animal production through the improvement of the productivity of indigenous pigs. Both of these arguments merit further consideration and lend weight to the current research emphasis. While sweet potatoes and pigs are important in both the lowlands and the highlands of Irian Jaya province, the central focus of this literature review is on the highlands, particularly the Baliem or Grand valley of the central cordillera, Jayawijaya regency. These central highlands, including the Baliem and Paniai regions, account for more than 90% of the total provincial sweet potato production (Karafir, 1987).

2. Context of Human-Sweet Potato-Pig Systems in Irian Jaya

2.1. Bio-Physical

The changes to the vegetation and the land in the Baliem valley postulated by Haberle et al. (1991:36-37) on the basis of pollen and sediment evidence from cores are:

1. Under natural conditions, the vegetation on the valley floor would be mixed montane forest.
2. The first human impact on the valley landscape may have occurred as early as 28,000 years ago.
3. The extensive alpine grasslands above 2200 m were being utilized at least 10,500 years ago.
4. Forest clearance by humans had occurred prior to 7,000 years ago.
5. Between 7,000 and 5,200 years ago dramatic opening of the forest had occurred.
6. From 5,200 to 2,900 years ago burning of grasslands and secondary forest for opening new gardens was well established, followed by partial recovery and stabilization of the forest, suggesting shifting cultivation with a long-term fallow on the valley floor and surrounding slopes.
7. Since 2,900 years ago, soil preparation through tillage has allowed for wide-spread use of grasslands for agriculture.
8. For the past 1,100 years, the development of silviculture and the adoption of a controlled tree-fallow system are evident.

According to Aditjondro (1982), Irian Jaya currently has three ecosystems, one of which is the alpine-montane ecosystem covering Jayawijaya and the Sudirman mountains of the Central Mountain range. The Baliem valley (1,500-2,000 m) of Jayawijaya is located at 138 degrees 30 minutes east and 4 degrees 0 minutes south, about 1,600 m. It has a humid climate with large temperature variation: a maximum of 24° C and a minimum of 11° C (mean daily temperature is reported as 15° C (Wiriadinata, 1995:87) and average temperature as19° C (Soenarto and Rumawas, 1997:55). Annual rainfall is reported as 1,800 mm, with 195 days of rain (Soenarto and Rumawas, 1997:55). The rainfall is seasonal in the Grand valley area, with the wetter months from December until April, when the Baliem River tends to flood (Haberle et al., 1991:26), and the direr months from June until October (Schneider et al., 1993), but there are no real dry months (Table 1). Nonetheless, drought can be a problem from June to September as the river is often low (Haberle et al., 1991:26). The intensity of solar radiation is low, with incident radiation of 1.38 $kJ/cm^2/day$, and average daily sunlight duration is only 3.98 hours/day. Because of a uniformity of climate, there is no planting season and no harvest season. One month is as favorable for planting as another (Gardner and Heider, 1968:40). Soils in the Baliem valley are developed from limestone, with poor native fertility. Phosphorus is relatively high while nitrogen and potassium are low (Schroo, 1963, cited in Soenarto and Rumawas, 1997:55).

2.2. Socio-Cultural

2.2.1. Humans

By 1982, Papua New Guinea (PNG) had about two million people, while Irian Jaya had about one million (Aditjondro,1982), or roughly 2.8 people per km^2 (Soenarto and Rumawas, 1997:55). By 1989, both the PNG and Irian Jaya sections of the highlands had a combined population of about 2 million, most of these in PNG (Brookfield and Allen, 1989:202). According to Achmady and Schneider (1995:73), the Jayawijaya division (47,960 km^2) of Irian Jaya province contains inhabited areas ranging from 700 to 2,900 m. The division is the most densely populated in the entire province, with 7.4 people per km^2. Parts of the division, like Eipomek valley, have reported densities of around 8 people per km^2, while the Baliem valley was reported to have a density of $60/km^2$ in 1982 (Scheifenhövel, 1982:830), apparently rising to $266/km^2$ by 1997 (Soenarto and Rumawas, 1997:55). Aditjondro (1982) claims, based on a classification by Douglas Newton (1979; cited in Aditjondro, 1982), that the Melanesians of West Irian can be divided into four major cultural groups, one of which is the central highlands cultural group, which includes the central highland group of PNG.

Evidence suggests that people have been present in the highlands of New Guinea for at least the past 25,000-30,000 years (Gorecki, 1986; cited in Haberle et al., 1991:25). Although there are substantial differences in patterns of settlement, social organization, and agricultural systems, the people of the more densely populated highland valleys are remarkably similar in basic culture and livelihood from one end of the ranges to the other (Brookfield and Allen, 1989:202). There exists an almost universal dependence on sweet potatoes and pigs.

2.2.2. Pigs

Pigs were one of the first meat animals to be domesticated. Archeological evidence suggests that pigs were first domesticated in Thailand over 10,000 years ago, as part of the system of shifting cultivation. Even today, in villages near forests, wild pigs are often captured, and most domestic pigs in these areas have considerable wild genes in them since they often forage in the forests where they crossbreed with wild boars (McNeely and Sochaczewski, 1988:170). Pigs were taken along by the early Austronesian explorers when they settled Polynesia several thousand years ago, though it appears that the sailors got so hungry on their long trip to New Zealand that they ate their pigs, and Maoris had no pork until the Europeans arrived (McNeely and Sochaczewski, 1988:170). The pig is the most important domestic animal in New Guinea, probably introduced to the island from Asia as domestic stock over 5,000 years ago (Purdy, 1971; Harris, 1975; Brown, 1978; all cited in Walters, 1981:275). However, the date of its appearance in the highlands of New Guinea is not well known. Golson (1997:44) says archeological evidence is sparse prior to 1,000 years ago, suggesting that controlled breeding under conditions of full domestication occurred around this time.

Golson (1997:43) argues that faunal impoverishment in New Guinea, caused by forest disturbance and destruction, set the scene for intensification of pig husbandry, which had to be supported from increased agricultural production, because availability of forage for pigs was reduced by vegetation changes. Kelly (1988; cited in Golson, 1997:43-4) suggests an alternative pathway, where initial expansion of secondary forest resulting from clearance created favorable conditions for forage-based pig husbandry, but subsequent human population increases upset the balance. Therefore, fodder replaced forage in order to maintain existing pig:people ratios. As Golson (1997:44) notes, both pathways suggest that the fully domesticated pig represented a scale of investment that raised its cultural status and made it an appropriate item in social exchange. Hide (2001) has recently compiled an exhaustive review of the literature on pig husbandry systems in New Guinea, which includes government livestock policy and pig research, as well as anthropological and other research themes and topics from 1960 to 2000.

2.2.3. Sweet Potatoes

Nine thousand years ago, an early form of horticulture moved up from lower altitudes to the highlands, with a switch to agriculture around 2,000 years ago, mostly yams (*Dioscorea* sp.), taro (*Colocasia* sp. and/or *Xanthosoma* sp.) and bananas (*Musa* spp.). A major change occurred when the tropical American sweet potato (*Ipomoea batatas*) appeared within the past several hundred years and its rapid acceptance as the dominant staple due to greater edaphic and/or altitudinal tolerances than existing crops and its superiority as pig food (Golson, 1997:40, 44-5). The highland societies of Irian Jaya (and PNG) are today dependent on one root crop, the sweet potato. Although a wide range of other crops is also grown, nowhere does the share of land and labor devoted to other crops exceed 25% (Brookfield, 1991:204). The most commonly held view is that *Ipomoea* arrived after the Iberian exploration 400 years ago via the Philippines and Indonesia (Yen, 1974:317, cited in Schneider et al., 1993), and even later (250 years ago in the Wahgi valley of PNG) in more remote areas (Golson, 1990:407). Some Ipomoea varieties may have been introduced earlier via Polynesia (Golson, 1977; Gorecki, 1986; both cited in Brookfield and Allen, 1989:202). Watson (1965, cited in Schneider et al., 1993) hypothesized an "Ipomoean revolution," though others (Brookfield and White, 196;: Yen, 1974; all cited in Schneider et al., 1993) consider changes less revolutionary. Yet the "comparative advantage" of *Ipomoea* (increasing land and labor productivity) undoubtedly exerted some influence on human and animal populations alike (Yen, 1974:320; cited in Schneider et al., 1993). Golson (1997: 48) provides evidence for a late, post-Magellanic entry of the sweet potato into New Guinea, against earlier claims by some, including himself, of an introduction from the Pacific around 1,200 years ago.

The rapid adoption and spread of sweet potato is attributed to (1) higher adaptability to environmental factors such as drought, low temperature and low soil fertility compared to other staples, and (2) higher productivity combined with suitability as a pig feed. Sweet potato allowed highland societies to shift their subsistence base from hunting to horticulture and raise more pigs that do not favor taro feed. By sustaining greater numbers of pigs, sweet potato changed not just agriculture but also socio-political structures forged by exchange practices, since pigs play a big role in highland exchange systems (Schneider et al., 1993). As prime pig fodder that could be grown over a wide range of soils and environments, including depleted soils and high altitudes, the sweet potato extended the possibilities of pig husbandry to more men, who through the labor of their wives thus entered previously restricted exchange systems in which pigs were central (Golson, 1997:49). Pigs in particular establish the exchange of women between kin groups through marriage arrangements. If a community did not convert to sweet potato, it could produce less pigs than neighboring communities that had switched, thus its position as an exchange partner would be weakened (Schneider et al., 1993). Watson (1977:60) calls this the "Jones-effect" and claims that pig-keeping is the additional force that makes the Ipomoean conversion of people after people a compelling force for their neighbors.

2.2.4. Human-Sweet Potato-Pig Systems Relationships

To assist understanding of the relationships between people, crops and livestock in the highlands of Irian Jaya, Schneider (pers. comm.) suggests that a distinction be made between the Grand Valley Dani in the Baliem River valley (language: Dani; center: Wamena), and the Western Dani (language: Lani; center: Tiom). Schneider suggests that this differentiation is also agronomically significant because the Western Dani have no access to flat, alluvial land and therefore no valley cultivation system (*wen-tinak*, or *hipere wen*). Another relevant distinction according to Schneider (pers. comm.) is Ploeg's (1966; 1989) between the Grand Valley Dani and the Dani of the Bokondini area. Living at lower altitudes, these latter groups have a much larger choice of crops including fruit they grow for the emerging market of Wamena (Schneider, pers. comm.). Because of the geographic scope of action for the present project, this review is primarily concerned with the Grand Valley Dani.

The Dani of the Grand valley of Irian Jaya are today swineherds and sweet potato cultivators, maintaining complex ditched garden beds worked with simple digging sticks. Each family or compound with a man and woman is relatively independent in this subsistence economy (Heider, 1970). There is seldom a day when Dani women do not spend several hours in their gardens (Gardner and Heider, 1968:40). Among the Dani, all adults are horticulturalists and herders. The only people who are not continuously engaged in sweet potato cultivation and the tending of pigs are the young, the senile, and the sick and wounded (Heider, 1970:61).

Schneider et al. (1993:30) underscore the socio-cultural links between humans, sweet potatoes and pigs when they describe a garden ritual (Dani, *hipere angkuduhwaknen*) conducted by a garden magician (Dani, *wako aipalek*) before the first sweet potato is planted. Three to five pigs are slaughtered, some of their blood retained in a gourd and splashed around the garden. Almost every major event in human life, including birth, initiation, bride purchase, marriage, death and the settlement of debts and grievances, involves ritual slaughter of pigs (Walters, 1981:275). In some highland societies, like the Eipo in Irian Jaya, leadership is exercised by "big men" (Eipo, *sisi-nang*), who reach such positions in part by being from a family with a large number of well-respected members who own much garden-land [i.e., sweet potatoes] and many pigs (Schiefenhövel, 1982:830). Roy Rappaport (1968; cited in McNeely and Sochaczewski, 1988:174-5) describes a roughly 12-year cycle of massive sacrificing of all the Maring pigs in a *kaiko* ceremony, followed by several months of fighting, and then rearing more pigs as part of a complex ecosystem that effectively adjusts the size and distribution of the Maring's human and animal populations to available natural resources. Rappaport concludes that the regulatory function of ritual among the...Maring helps to maintain an undegraded environment, limits fighting to frequencies that do not endanger the existence of the regional population, adjusts man-land ratios, facilitates trade, distributes local surpluses of pig in the form of pork throughout the regional population, and assures people of high-quality protein when they most need it.

McNeely and Sochaczewski (1988:314) note, however, that because of the changes that have come with the world marketplace, pigs are no longer effective in maintaining the ecosystem balance of the Maring. As the pig slowly assumes a greater nutritional role than the previous social and cultural role, the need to evaluate its feed, and efficiency of usage increases (Rose and White, 1980:69). Golson (1997:50) highlights massive transformations in Highland New Guinea, wrought by the practice of shifting cultivation, which took place over millennia, and affected agricultural practice, pig husbandry, and social exchange systems. The entry of the sweet potato wrought even more changes, still taking place at the time of European contact. Nowadays, the cash economy and rising populations are affecting natural and social systems at unprecedented scale and speed.

Aditjondro (1982:66) cites three major cultural conflicts in Irian Jaya, since becoming part of Indonesia, two of which concern pigs and sweet potatoes. In the early 1960s there was an attempt to purify the Irianese economy and way of life from pigs, the taboo animal of the Indonesian Muslims then arriving to the new territory. The result was that the hill tribes went back to hunting. According to Ryan (1969:355-6, cited in Aditjondro, 1982), this was the main reason for the subsequent massive importation of Australian pigs and cattle in 1969. Apparently Muslim missionary organizations made concessions by permitting consumption of pork among early Irianese converts. The other cultural conflict discussed by Aditjondro (1982:66) was a drive to change the staple food to rice, which actually began under the Dutch administration. By 1982, half a million rice farmers from Java and Bali were to be resettled in Irian Jaya, in order to change the province into the nation's "rice barn." Dumped with so much rice, apparently a substantial number of Irianese have since switched from sago and sweet potatoes to a predominately rice diet.

As for these apparent cultural conflicts with Indonesian mainstream culture, Schneider's (pers. comm.) judgment is that the concern with rice persists while the concern with pork is of minor importance. Attempts to Islamicize the Irianese have been largely unsuccessful, he notes. Most Irianese are Christians, something which unites them as Papuans across tribal identities, and this entails also pork consumption (Schneider, pers. comm.).

3. Sweet Potato Cultivation and Consumption

The 300 years of the *Ipomoean* period are characterized by adaptation and elaboration of agro-technology including systems of tillage, mounding, drainage and mulching, expansion of fallow-regrowth enhancement through tree planting, slope and wetland management (Brookfield and Allen, 1989:204).

Throughout New Guinea, sweet potato is the most important subsistence crop; however, in PNG it is also a significant cash crop, where large quantities in both the lowlands and highlands are grown for sale in markets and to institutions (Bourke, 1977:73). In Irian Jaya, it appears that sweet potato is only important as a subsistence crop, both for humans and for pigs. It is estimated that 60% of the population in Irian Jaya consume sweet potato as their staple food, even more in the mountainous areas (Tubun and Karafir, 1990). The staple food of the Dani is sweet potato accounting for about 90% of the Dani diet. Heider (1970) uses the term *hibiti* for sweet potato in his early work on the Dani, while Schneider (pers. comm.) later only heard the term *hipere* (or *ipere*) used by the Dani. Sweet potatoes in Irian Jaya (and PNG) are mostly grown in a restricted zone where climatic factors, especially frost risk to agriculture, put an upper limit of 2,300-2,450 m (with the extreme at 2,750 m) on cultivation. There is also a lower limit (usually 1,200-1,500 m) below which human settlement is scarcer and different agricultural systems are in place (Brookfield, 1964, cited in Schneider et al., 1993). Heider (1970) notes that below 1,200 m in the Jalemo valleys of Irian Jaya, sago grows in addition to sweet potato.

In Irian Jaya per capita sweet potato production is approximately 100kg, with total annual production of 180,000 metric tons (Prain et al.,1995). The average production of sweet potato in Irian Jaya is considerably low compared to that obtained from research plots, according to Tubun and Karafir (1990). They report that productivity in farmers' fields over a ten-year period, varied from 5 to 10 t/ha, as compared to 30 t/ha in research plots. Some estimates put sweet potato as the staple food of 95% of the population in the highlands, with daily sweet potato consumption estimated at three kg per capita, or 13 kg per average family (Soenarto, 1987; cited in Achmady and Schneider, 1995:73). When individual sweet potato consumption estimates are combined with population data to calculate aggregate consumption needs, and then compared with annual production statistics, a phenomenon of food shortage appears in Jayawijaya Regency (Karafir, 1987). Karafir (1987) states that the prime cause of this sweet potato shortage is rapid population growth and restrictions imposed by tribal rights resulting in arable land shortage. Another factor he cites is the stagnant or decreasing productivity of the land in some parts of the region. Although now some 16 years old, the review of sweet potato production and research in Papua New Guinea published by Bourke (1985a) provides a thorough assessment of the crop in traditional systems, as well as a synthesis of agronomic field trials have been carried out.

3.1. Sweet Potato Production Systems

Although wooden and stone tools have now been almost universally replaced by steel ones, the basic cultivation systems in the highlands remain largely unchanged, utilizing hand labor without benefit of either livestock or machinery (Brookfield, 1991:204-5). Sweet potato is cultivated in nearly every agro-ecosystem of Irian Jaya, from the coast up to almost 3,000 m (Achmady and Schneider, 1995:71), sometimes characterized as follows (Matanubun et al., 1995:57):

- sweet potato has been cultivated for generations
- its scale of production is quite small
- its cultivation employs simple techniques
- it is mostly cultivated for home or subsistence consumption

However, there is a multitude of descriptions of sweet potato production systems in the literature, and other descriptions of highland cultivation systems exhibit great variation, some of which appear neither small scale nor simple. Many of the descriptions, and resulting typologies, are based on local terms, which has also confounded characterization and classification. Since this review is primarily concerned with the greater area of the Grand Valley of the Baliem River, and for purposes of clarification and standardization, two basic cultivation systems are identified and characterized as “valley” and "upland" systems, following the suggestion of Schneider (pers. comm.). Nevertheless, some discussion of variants in the literature is first warranted.

Unlike sweet potato production systems in PNG, all of which represent various systems of shifting cultivation according to Sowei (1993:77), those in the highlands of Irian Jaya are semi-permanent to permanent (Karafir, 1987:318; Schneider, pers. comm.). According to Brookfield and Allen (1989:204), three basic groups of agronomic systems emerged in the highlands, each characterized by considerable local variation in detail. To some degree these seem adapted to edaphic conditions, though recent work casts doubt on this assumption (Bourke, pers. comm.; cited in Brookfield and Allen, 1989:204). Soenarto and Rumawas (1997:56), on the other hand, distinguish two general sweet potato production systems carried out by the Dani on the basis of wet soil and dryland cultivation systems. Heider (1970) claims that based on his observations, there are actually three main types of gardens. In addition to the extensive ditched gardens on the valley floor, and the hill slope gardens, a third type is the gardens at the compounds, though these do not seem to contain sweet potato. Wiriadinata (1995:88) only distinguishes two types of Dani garden bed, *wen*, located some distance from their homes, and *wen ililu*, planted very near to their homes. Schneider et al. (1993:20) group gardens into two different types that differ in size, crop mixture, tenure and other characteristics:

- "big garden" (ld. *Lokalek-ma*: l. *yabu buluk ago*) of several hectares, a communal undertaking, mostly sweet potato.
- "small garden" (or "home garden" or "mixed garden") of 10-30 aren, belonging to individual households or nuclear families, with varied crop mixtures increasingly converted to growing cash crops for Wamena.

Sweet potato cultivation among the Dani, as in most highland societies, is considered women's work (Schneider et al., 1993). There are, however, some inconsistencies across the New Guinea highlands. For instance, in Wola (PNG) society women are the cultivators of sweet potato, but the sweet potato itself is conceived as a "male crop." This anomaly of sweet potato underscores the importance of sweet potato and reallocates it to the male domain (Sillitoe, 1983).

The garden cycle in the highlands of Irian Jaya begins when the sweet potato crop is planted, and ends when the remainders of this or a subsequent crop are left to the pigs. These cycles last between one and a half to three years for gardens with no internal rotation (Schneider et al., 1993:22). There is no standard time or schedule for any of the cultivation operations. Crops are planted irregularly but harvested daily (Heider, 1970:41, 61). Schneider et al. (1993:22) concur that planting activities are not strictly seasonal. However, gardens are generally cleared, fenced and tilled from January to March, and planted between April and July. Since there is virtually no storage of sweet potato, harvest is as continuous as possible, and new gardens that replace the old have to be prepared in time (Schneider et al., 1993:22-3). Wiriadinata (1995:88) claims that sweet potato is harvested five or more months after planting. In a seasonality trial in PNG, Kanua (1990; cited in Sowei, 1993:78) reported a production life of 12-24 months for a local variety.

Soenarto and Rumawas (1997) found that the main constraints for sweet potato production in the Baliem valley were:

- soil texture (clay loam with a block structure rather than the sandy loam with a crumb structure that favors sweet potato because of high content of organic matter)
- high water table, instead of the good drainage favoring sweet potato
- low radiation intensity, instead of high solar radiation that favors sweet potato
- low air temperature, which is also unfavorable for sweet potato
- low levels of soil potassium, whereas sweet potatoes require higher levels

3.1.1. Valley Systems

On the Grand Valley floor of the Baliem River there is one basic type of cultivation system (Schneider et al., 1993; Soenarto and Rumawas, 1997):

- *Hipere wen* or *wen-tinak*, though *wen ipere* and *ipere wen* are also used in the literature (planting in mounds on flat raised sweet potato beds with a developed drainage system on the Baliem valley floor with cultivation periods up to five crops or six years and fallow periods of five to ten years): the source of most of the food (Heider, 1970:33): up to 200 cultivars planted in this system (Achmady and Schneider, 1995); Schneider et al., (1993:12) prefer the term *ipere wen* because they claim it is the correct form according to Dani grammar; however, although Schneider (pers. comm.) does not know the meaning of *tinak*, he feels this may be a good choice, as not only sweet potatoes are grown on these raised beds, but also (some) vegetables, and an occasional yam, etc.

This however does not imply that all communities in the valley practice this system only – on the surrounding slopes, upland systems (*yawu*) are in place, and many villages have parts of their land under *wen-tinak*, parts under *yawu* (Schneider, pers. comm.). Moreover, Soenarto and Rumawas (1997:56) claim that dryland gardens are not only those on hillsides, but also the majority of those on the valley floor where the soil has a low water table. Only lands adjacent to watercourses are used in the wetland system. According to these two researchers, w*en-tinak* is the local name for wetland sweet potato gardens cultivated on soil with a high water table in the vicinity of swamps, around ponds or in the course of rivers in the bottom of the Baliem valley. Among the Dani of the Baliem valley, the *wen-tinak* complex system of raised beds, mounds and canals devised by their ancestors represents the conversion of unfavorable conditions into an environment with improved physical and chemical conditions favorable for sweet potato cultivation (Soenarto and Rumawas, 1997:66). In the west-central PNG highlands, the mounding system roughens the surface and provides some air drainage, both conditions that adapt it to the cold (Brookfield and Allen, 1989:204). Waddell (1972; 1989; both cited in Brookfield and Allen, 1989:204) regards the mounding as an adjustment primarily to the recurrent hazard of light ground frost. However, Bourke (pers. comm.; cited in Brookfield and Allen, 1989:204) thinks it more likely that the main purpose of the mounding is to keep the tubers dry, and to accommodate composting to enhance soil fertility.

The *hipere wen* cultivation system in the valley is described in detail by several researchers (Yen, 1974: Achmady, 1988: Soenarto, 1987: Golson, 1990, all cited in Schneider et al., 1993). According to Schneider et al. (1993), after clearing and burning the vegetation, the soil is tilled. Small beds of less than five aren are raised by deeply dug drains. Large areas of four to ten hectares are drained in this manner and divided by a system of main ditches. In time of drought, cross-dams retain water in the ditches (Veldkamp, 1958, cited in Brookfield, 1964:22). Cuttings (about 60 cm long) are taken by women a day or two before planting and stored in a hole in the ground covered with grass. The sweet potato is planted in mounds (about 60 cm in diameter and 70 cm apart) on top of these beds by bending and covering the cuttings, leaving only about 15 cm of the tip free. Usually three to five cm cuttings from the same variety are planted in the mounds (Matanubun et al., 1995:59). The Dani plant their sweet potato beds with a mixture of 10-40 varieties, with a knowledge of each variety planted (Schneider, 1995c:65). Across the Jayawijaya division, between 20 to over 100 cultivars are planted in any one garden compound (Achmady and Schneider, 1995:74). Bourke (1985a) estimates sweet potato planting density in PNG subsistence systems between 15,000 to 170,000 cuttings/ha, by varying both the distance between plants and the number of cuttings at each planting site. Yen (1963, cited in Schneider et al., 1993) notes that a consistent characteristic throughout highland New Guinea is propagation by vine cuttings, only rarely by planting tubers, and never by intentional planting of natural seed. After planting, mud and green manure is lifted from the drains and smeared onto the mounds. Three to five months after planting, weeds are removed and sweet potato vines are reversed and cut back (pruned) and either tossed in the ditches where they become part of the compost (Heider, 1970: 42), used as pig feed, or used as a supply of cuttings for the next cycle. Some leaves are picked after the vines have reached at least 40 cm, usually the four or five leaves below the tip (Schneider et al., 1993:32). Depending on the primary use of the product either shoot or tuber development can be promoted by means of location or methods of soil tilling via soil temperature (Fischer and Karnatz, 1992:71).

In the *wen-tinak* wetland cultivation system described by Soenarto and Rumawas (1997), a simple gate connecting the main canal to a river controls the height of water in the canals. The system involves preparation of raised beds five to 20 m long, two to three m wide, surrounded by ditches one m deep and one and a half m wide. A wetland garden of 20 to 30 ha, derived from five to seven year-old fallowed garden or forest, is collectively prepared and owned. Three to four weeks after planting, the apical shoots are cut, and the plants with long stems are pruned five months after planting, each time the women visit the gardens, and used as planting material or eaten as vegetables. Five to six months after planting, all new fibrous roots growing on the bottom on the plant or on the tubers are cut. Crops are harvested beginning in the eighth month after planting.

Soenarto and Rumawas (1997) found (and quantified) that in the Dani *wen-tinak* system:

- water in the canal system decreases the amplitudes of soil temperature waves in the raised beds (21 degrees C at 5 cm depth, ± 3.3 degrees C)

- the raised beds (78% moisture) and mounds (lower=48%, middle=40% and upper=25% moisture) provide a slightly drier environment that favors tuber formation
- mounds favor light interception by leaves and vines and increase surface area, thus reducing mutual shading
- the water filled ditches/canals serve as a nutrient trap, thus the mud which is dredged and applied to the mounds is comparable to fertilizer application (similar to the effect of sewage sludge applied to agricultural lands) high in both total and available K, and helps improve soil structure through addition of organic matter

On the Grand valley floor, perhaps half the land at any one time will be fallow. The ditch system constitutes some 20 to 40 percent of the total flat garden area. Probably ditches were originally dug to reclaim the land from the valley swamps, and now serve for both drainage and irrigation (Heider, 1970:42). The series of levees and dams also helps to control the water table by allowing excess water to be redirected during floods and stored during droughts (Haberle et al., 1991:29). Perhaps the most important function of the ditches is fertilization when the mud and organic matter from the ditches is smeared onto the sweet potato mounds (Heider, 1970:42). Settling of blue-green algae produces nitrogen-rich mud on the ditch walls, which is used to fertilize the sweet potato crop. As the ditches become more acidic due to the accumulation of humic acids, the algae die, the nitrogen is reduced and the garden plot is fallowed (Haberle et al., 1991:29-30).

Soenarto and Rumawas (1997:63) conclude that the *wen-tinak* system devised by the Danis' ancestors not only improves but also maintains soil fertility, and is in fact similar to:

- *Chinampa* agriculture conducted by Aztecs in the Mexico valley several hundred years ago (Cox and Atkins, 1979)
- *Tiwanakan* drainage systems devised by ancestors of the Aymara Indians in the Andean highland villages of Bolivia (Knox, 1991)

Golson (1990) suggests that the *hipere wen* system was first developed for taro then modified for sweet potato, and Soenarto (1987:62) concludes that it represents a modification of an adverse environment into one with physical and chemical properties that favor the sweet potato. The nutrient cycles in the *wen-tinak* system are shown in Table 2 (Soenarto and Rumawas, 1997:64-64). Another intensive type of cultivation, in addition to the *wen hipere*, is the *bedamai* system practiced by the Me/Ekagi/Kapauku tribes in the Wissel Lakes area (Matanubun et al., 1995:57).

3.1.2. Upland Systems

Dani hillside sweet potato cultivation (Dani, *yawu*) follows practices known elsewhere in the world as shifting cultivation. These are slash-and-burn systems, but an important qualification has to be made, at least for the Baliem valley: there, agriculture has been practiced for thousands of years, and tree vegetation has been removed in many areas. Thus, in contrast with "typical" slash-and-burn systems, these systems are more permanent in nature, with "maximum tillage" of the soil (Schneider, pers. comm.). Outside the Baliem valley, in the eastern border area of Irian Jaya (Oksibil), an area dominated by old growth forest, Schneider (pers.comm.)

has observed a “typical slash and burn system” (i.e., removal of tree vegetation, burning, dibble-planting with no soil tillage at all). These systems are described in more detail in Boissière (1999a; 1999b).

The *yawu* cultivation system is described in the literature (Heider, 1970; Achmady, 1988: Golson, 1990, all cited in Schneider et al., 1993):

- *Yawu* (planting on the slope, with several subtypes, involving regular land rotation and fallowing): classic slash-and-burn gardens, with more emphasis on taro and cucumber than sweet potato (Heider, 1970:36): According to Schneider et al. (1993), the presence or absence of mounds is used to distinguish the subtypes of *yawu.*

    - *Yabu waganak* (planting in mounds on beds drained by small ditches on naturally well-drained land in the valley and on medium slopes) up to 50 cultivars are planted in this system (Achmady and Schneider, 1995).
    - *Yabu enapipme* (panting on beds without mounds, but with complete soil tillage, on medium to steep slopes with drains that run across slope on the contour): again, up to 200 cultivars are planted in this system (Achmady and Schneider, 1995).
    - *Yabu alome* (planting directly with a dibble stick without prior tillage on very steep and/or stony slopes): even this system exhibits up to 150 cultivars (Achmady and Schneider, 1995).

As described by Gardner and Heider (1968:39), men, who ring the larger trees with stone adzes and allow them to die, do clearing of fallow bush. Later the men return with digging sticks and root up the brush, allowing it to sun dry, and then later burning the dry material, the latter done by either men or women. The final step is terracing, which is generally heavy work and done by men. Brookfield (1964:22) and Haberle et al. (1991:30) credit the highlanders of New Guinea with soil-erosion control practices, including contour planting, construction of temporary "soil fences" that give a terraced effect and decrease the slope by about five degrees, the use of contour hedgerows with *cordyline* bushes, and stone walls across the slope in the Baliem valley, permitting cultivation of slopes 45 degrees and steeper. Haberle et al. (1991:30) note, however, that very few of these stone walls appeared large enough to keep pigs from entering the garden areas, and some such areas of former cultivation are almost entirely denuded of soil.

According to Schneider et al. (1993), in the uplands cultivated areas of several hectares are fenced off with wooden or limestone enclosures. These compounds are divided up into furrow beds in regular rows that are worked and harvested by individual cultivators. Planting distances in flat beds are only about 15-20 cm. Restoration of fertility is enhanced through use of *Casuarina* species and pig/grazing manure. Golson (1990, cited in Schneider et al., 1993:14) documents agroforestry (a silvo-pastoral system with trees and grazing pigs) in the archeological record from 1,200 years ago. In Anggi, after the pigs have finished rooting old gardens and have been moved out, the garden may again be planted to peas, beans and other vegetable crops before finally being fallowed (Karafir, 1987:320). The period of fallow depends on the needs of the clan and the fertility restoration capacity of the land. Restoration of fertility is determined by local people who monitor the vegetation development of the fallowed land (Karafir, 1987:320). Generally, no mounding is practiced, because the steep slopes (>15%) make erosion of mounds likely, and thin top soils may provide insufficient volume for surface-covering mounding. Haberle et al. (1991:30) noted gardens with severe soil loss probably due to mounds that went up and down the slope, instead of on the contour.

Wiriadinata (1995:88) states that sweet potato cannot be planted in Dani gardens more than twice consecutively, so they practice a system of rotation, replanting in fallows, old swidden fields (5-10 years old), or secondary forest areas. Fallow and secondary forest are ready for replanting of sweet potato when indicator species, *sugun*, (*Wendlandia paniculata*) or *pabi*, (*Dodonea viscosa*) have grown about three to four meters tall and have produced flowers and fruit.

Other crops grown in association with sweet potato include taro (*Colocasia* sp.), yam (*Dioscorea* sp.), sugar cane, banana, gourd (*Lagenaria siceraria*) and tobacco (*Nicotiana* sp.) (Schneider et al., 1993).

3.1.3. Sweet Potato Productivity

Only roots big enough are harvested, the others are recovered with soil and left for the future. Each harvest is targeted for family size and the number of pigs fed on a near daily basis (10-15 kg will feed a family of three adults, three children and two big pigs). As there is no storage, most roots are consumed within a day of harvest. (Schneider et al., 1993:32-3). Using this technique, the harvesting can take place between months 10-14 (Matanubun et al., 1995:59). However, there is an almost linear relationship between altitude (thus air temperature) and time from planting to maturity, ranging from 17 weeks at 1,400 m to 49 weeks at 2,600 m; yet yield remains constant irrespective of time to maturity (Bourke, 1988; 1989; Clarke, 1989; all cited in Brookfield and Allen, 1989:202). Soeanarto and Rumawas (1997:56) report yields from wetland gardens between 20 and 25 t/ha of fresh roots, without chemical fertilization, whereas dryland gardens produce a maximum, without fertilization, of 10 t/ha. Enyi (1977; cited in Takagi, 1987:156) reports that subsistence yields of sweet potato range from 2-50 t/ha, with most values between 5-25 t/ha, while experimental yields have ranged from crop failure to 71.2 t/ha. When grown under AVRDC's lowland conditions, yields of PNG accessions were very low, ranging from 0.1 to 11.5 t/ha (Takagi, 1987:156), though it is recognized that most highland cultivars do not produce well in the lowlands.

Yields of sweet potato tips varied from 10 to 16 t/ha in weight and 61 to 352/m^2 in number, whilst yields of marketable roots from the same plants varied from 1 to 16 t/ha in 116 days in a study conducted by Villareal et al. (1979) in the Philippines. These yields, under conditions of low management, are comparable, and even better than some more conventional leafy vegetables.

Reported interactions between mycorrhizal fungi and sweet potato nutrition are limited, but the research conducted by Floyd et al. (1988:21) resulted in strong indications of the potential importance of mycorrhizal infection on sweet potato yields and phosphate nutrition under field conditions.

3.1.3.1. Mounding and Composting

As seen above, in most permanent and semi-permanent systems of cultivation in New Guinea, mounding along with incorporation of organic matter into the mounds is widely practiced. Floyd et al., (1988:16) suggest that while such composting rates vary from area to area, they seldom exceed 20-40 t fresh weight/ha, often substantially lower. They further suggest that the major factors determining composting rates are the availability of organic matter and/or the availability of labor for its collection. Sweet potato vines and weeds found on the mounds of the previous crop are widely used traditionally as composting material, along with fallow residues when available. Thus, composting rates are largely determined by the vine yield of the previous crop. In the experiments by Floyd et al. (1988:17), mean vine yield was 16 t/ha on the treatment that consisted of 20 t/ha of compost, within the range of normal composting rates in the subsistence system. This suggests to them equilibrium between vine yield and composting rates.

3.1.3.2. Weeding Competition and Weeding

The use of herbicides in PNG lowlands, and presumably throughout New Guinea, is very rare, so weeding is done by hand. For sweet potato, yield reduction due to uncontrolled weed competition can range from nil (Talatala, 1978; cited in Levett, 1992:64) to nearly 100% Unamma et al., 1985; cited in Levett, 1992:65). Levett (1992:69) notes that in the PNG lowlands, initial weed control is undertaken by hand at 28-42 days after planting (DAP), with infrequent weed removal thereafter. However, Levett's experimental evidence shows that this is too late to avoid competitive effects, and may actually interfere with tuberous root initiation. Delaying the commencement of weeding beyond 14 DAP significantly reduced vine weight, total yield, and mean number of tubers/plant. On the other hand, hand-weeding between 28-42 DAP appeared to have a detrimental effect on tuber initiation due to mechanical root disturbance, and regular weeding after 56 DAP produced lower yields as well, likely due to canopy disturbance (Levett, 1992:63). Thus the possibility of crop losses due to excessive weeding must also be considered. In order to minimize (1) weed competition during the critical period, (2) root and vine disturbance during the sensitive period of tuber initiation, and (3) vine canopy disturbance in the latter part of the cropping cycle, Levett (1992:69) recommends the following hand-weeding program. Weeding at 7-10, and 14-21 DAP, no disturbance between 21-28 and 42-56 DAP, a further weeding about 56 DAP, and infrquent weeding thereafter. Where resources are limiting, like social commitments and labor constraints, he suggests that a single weeding around 14 DAP appears to be very effective, depending on cultivar, growing conditions and the main weed species.

3.1.3.3. Fertilization

In a review of over 20 years of fertilizer trials in PNG, Bourke (1977) found that sweet potato yields are very responsive to the application of certain nutrients, particularly nitrogen (N). It should be noted, however, that all of these trials were conducted on recent volcanic soils, which are not found in Irian Jaya. Nevertheless, Bourke (1977:73) found that N had the greatest effect on yield, giving large yield increases, especially at grassland sites. Notably, differential responses to N were likely varietal differences, and in all trials N increased top growth vigor and color, and in most cases weight. Phosphate (P) improved top growth vigor to some degree, and improved tuber yield in only a few trials. Large yield responses to potash (K) were recorded, which did not affect top growth but did increase tuber number. Bourke (1977:89,94) found that N is clearly needed in both grassland sites and former forested areas where cropping has reduced soil fertility, and should not be applied late in the life of the crop. Furthermore, he states that the requirement for N fertilizer could be reduced by either a fallow, or by rotating sweet potato with another crop like peanuts. Potash, according to Bourke (1977:92) is obviously needed in former forest areas where soil fertility has been reduced. He also reports that results from a pot study indicate that magnesium and manganese are required on intensively cropped soil, and can possibly become limiting. No indication of a sulfur requirement was reported. Finally, he notes that mixing fertilizer and soil during ridging or mounding may result in more efficient fertilizer use.

Floyd et al. (1988) investigated the relationship of soil fertility and sweet potato production in PNG. Although their work was carried out on volcanic ash soils, of which there appear to be none in Irian Jaya, nevertheless some implications can be drawn from the results of their research. They found, on predominantly volcanic ash soils, that soil fertility, particularly that related to phosphate and potash nutrition, is the fundamental constraint to yield. Sweet potato yield responses to phosphate and potash application were predominantly asymptotic, while those in response to organic composting were predominantly linear. This indicates substantial potential to increase yields by incorporation of more organic matter, specifically grasses, into sweet potato mounds in traditional systems. On the other hand, despite large yield increases from phosphate and potash, only potash application proved economical. They found no significant interaction between phosphate and potash on any of the soils they tested. Bourke (1985b:373), however, states that the relative importance of N (and presumably other nutrients) on sweet potato yield will depend on the soil fertility at the site.

It is worthwhile to reiterate the importance and ubiquity of traditional methods of fertilization, specifically the application of mud and green manure from the ditches onto sweet potato mounds in the *wen-tinak* system. This technique has been analyzed in agronomic terms by Soenarto (1987), perhaps the best agronomic study so far of *wen hipere* agriculture in the Baliem valley (Schneider, pers. comm.).

3.2. Sweet Potato Cultivars

Native peoples look for diversity in their cultivated crops in order to minimize risk of damage from adverse factors like diseases, pests and abiotic factors (Plarre, 1995). Indeed, as shown in other research, choice of appropriate varieties is very important (Fischer and Karnatz, 1992:71). Planting a large number of cultivars also allows some variation in an otherwise monotonous diet (Schneider et al., 1993:30). The large variability is derived from mutations and segregation after seed setting and selection of seedlings, which are multiplied as clones (Plarre, 1995). In addition, the cultural isolation of growers and growers' taste preferences contribute to the explanation for the large number of cultivars through New Guinea (Takagi, 1987:147). The clonal propagation of specific cultivars by cutting the vines contributes significantly to the maintenance of the number of accessions in a given area. Moreover, the planting of various varieties in a given place may enable cross pollination which in turn will result in the creation of new accessions (Matanubun et al., 1995:59). However, the system of vegetative propagation does not support genetic recombination (Schneider 1995c:66). Brookfield (1964:21) notes that in fact there is little evidence that highlanders practice much rational sweet potato selection. There is a constant replacement of cultivars, and at most locations in the highlands of PNG, a high proportion of the cultivars currently in use are recently adopted (Brookfield and Allen, 1989:208). These authors note that a process of selection over time has certainly taken place, although it has not yet been analyzed.

Propagation of sweet potato in Irian Jaya has three basic characteristics (Schneider et al., 1993:30):

- it is asexual and continuous leaving scant chance of genetic recombination
- it occurs mostly within households, with each women possessing a complete set of clones more or less
- sexual propagation through seed is incidental and not systematically exploited by farmers

3.2.1. Cultivar Diversity

The estimate given for PNG by Bourke (1985a:94) is 5,000 cultivars grown by farmers, with about 900 cultivars maintained on research stations, though Takagi (1987:148) states that about 1,800 accessions are maintained in PNG. Total number of cultivars now grown in any single area or community varies between 6 and 71. Of these, the number of traditional cultivars varies between 11 and 45, the number of post-contact introductions varies between 2 and 32-42, and the number of traditional cultivars now lost varies between 16 and 30-40 (Bourke, 1985a:97). In the western highlands (Irian Jaya), a conservative estimate is well over 1,000 local cultivars, with the number in a single area or community ranging between 28 and 81 (Schneider et al., 1993). Table 3 shows the number of sweet potato cultivars grown by various groups in Irian Jaya. During the Japanese occupation of the Gazelle Peninsula of PNG, sweet potato plants might have introduced between 1941 and 1945. Most introductions of new cultivars in the Baliem valley come from bible school students who originate from elsewhere (Schneider et al., 1993:41).

3.2.2. Cultivar Collections

Schneider (1995c:63) has participated in the collection and documentation of about 450 cultivars in this area. Previous research in Irian Jaya collected 139 cultivars in the Paniai area (Matanubun et al., 1991, cited in Schneider et al., 1993) and 500 accessions in the Baliem valley (Sawor et al., 1993, cited in Schneider et al. 1993). Schneider et al. (1993) collected about 224 accessions in the Baliem valley, whereas in Anggi only about 60 accessions were reported by Sawor et al. (1993, cited in Schneider et al., 1993). CIP ESEAP collected 224 accessions (98 from between 1,500 and 1,700 m on the Baliem valley floor, 76 from 1,900 to 2,400 m in the intramontane valleys of the Tiom area, and 49 from the Pugima area were contributed by collaborating extensionist, Achmady). The collection is maintained both at the fields of the Agricultural Faculty of UNCEN in Manokwari (50 m) and the Horticultural Research Institute in Lembang (1,250 m). A subset is also maintained at the fields of the LIPI botanical garden, Honailama, Wamena (Schneider et al., 1993). Plarre (1995) collected numerous clones in 1979 in Kosarek (45) and Eipomek (50) in the highlands of Irian Jaya, many of which were replanted in a breeding garden at Kosarek. Some clones were specifically tested for their reaction to different soil temperatures under greenhouse conditions. Takagi (1987:148-9) details the status and characterization of the PNG sweet potato collections.

3.2.3. Cultivar Description and Nomenclature

The high number of variety names suggests one of two hypotheses (Heider, 1969:78): (1) it is just play or and intellectual elaboration: (2) it is functional in that it serves to differentiate the plants by distinct properties, ecological adaptation or ritual functions. Heider (1970:33) notes that although there are more than 70 terms for sweet potatoes among the Dani, they are used with considerable imprecision. Individual women seem to use only 40 to 50 names. A few kinds are recognized as especially tasty, and a few are seen as being only fit for pigs. In most cases, it is not clear if the names of clones have special meaning, although sometimes there is a connection to a specific locality from which the cultivars have been introduced. Some names can be directly translated, like *wisen* which is the greenish-yellowish color of parrot (*Charmosyna papou*) plumage (Plarre, 1995).

Schneider (1995:65) notes that the Dani language consists of three major dialects and many minor variations. There is considerable overlap of cultivar names across the dialect areas. Gastronomic characteristics are most easily solicited knowledge about sweet potato varieties. Yet after morphological examination of material collected in 1993, Schneider concludes that the large number of names do represent distinctive varieties. Local perception as represented by distinct names corresponds closely to taxonomic characters developed by plant geneticists (leaf shape and pigmentation, and some characters of the vine, but not the root). Achmady and Schneider (1995:74) cite several examples of morphological and other characteristics that vary widely among varieties, including cultivars that produce just one very large root per plant: cultivars with rolled leaves that look like scab infestation: cultivars with bright leaves: and cultivars with roots containing a purple flesh and relatively high carotene content. Plarre (1995) was really surprised by a young highland girl who showed him that two sweet potato clones that he (a breeder) thought were identical, actually were not, as one had fine-haired stems and the other naked stems. Gardner and Heider (1968:39) claim that by the time a child is ten or twelve, he recognizes most cultivars by their blossom, vine and root. Many varieties of sweet potato vary in color of both skin and flesh, which may indicate variation in levels of carotenes (Rose and White, 1980). They also vary in the level of nitrogen, from 0.3% to 1.1% (White, unpublished data, cited in Rose and White, 1980). Plarre (1995) claims that both skin (red, yellow and white) and flesh (reddish, yellow and white) color of sweet potato tubers serve to identify clones. He compiled a chart of color classes and found a correlation with environmental conditions. At higher altitudes red, skinny tubers are preferred because they seem to have a selection advantage of anthocyanins, which have a metabolic function of protection against disease infection and adverse conditions of cooler soils. But their quality is adversely affected. However, red, skinny tubers mostly have white flesh with a better taste, and these have been selected. So there is a free combination of skin and flesh characters. Sawor et al. (1993; cited in Schneider et al., 1993) break down cultivars by root skin color, earliness, plant type, texture and taste.

Sowei (1993:79-80) and Takagi (1987:149) note that descriptions of some collections in PNG have been done using the descriptor list of the International Board for Plant Genetic Resources (IBPGR), with some modifications (27 descriptors). Others have been described using only six characters (Takagi, 1987):

- immature leaf color
- abaxial leaf vein color
- vine pigmentation
- leaf shape
- tuber skin color
- tuber flesh color

Fischer (cited in Heider, 1969:80) describes the attributes which define the different varieties as:

- form of tuber
- color of skin
- color of meat
- consistency of meat
- shape and/or color of leaves

Prain et al. (1995:711) cite skin color as the principal criterion for classifying sweet potato varieties in Irian Jaya, though admitting that some informants used flesh color. They claim there are three main varietal classes based on skin color:

- "reds"
- "whites"
- "yellows"
- plus a residual fourth category.

Heider (1970:31), working in the Baliem valley, claims that sweet potatoes fall into two major categories by flesh color:

- grayish or cream-colored meat
- yellow or orange meat (*hibiti modla*, light)

Schneider et al. (1993:37-8) were able to distinguish eight groups of cultivars among the Dani:

1. Analogies with other plants
2. Analogies with animals
3. Analogies with other objects
4. Origin
5. Evolution
6. Use, or association with ceremonial/lifecycle events
7. Gender
8. Taste

3.2.4. Cultivar Use and Adaptation

Regarding specific cultivar uses, Achmady and Schneider (1995:74) found cultivars with fibrous roots used as pig food, cultivars with high starch content and sweet taste reserved for ritual and ceremonial use, cultivars only eaten as a leafy vegetable, cultivars for medicinal purposes, and cultivars planted near fences and used to tie up fences with their vigorous vine growth. Schneider et al. (1993:42) produced a table of cultivar-specific information, including those for baby food (25 cultivars) and those for pig forage (16 cultivars). Those fed to pigs are big and fibrous and eaten by humans only during times of food shortage. Small and damaged tubers are also fed to pigs, but some informants insist that pigs can only grow big quickly on specific cultivars (Table 4). Cultivars from Irian Jaya that are known as pig feed (*hulok*) have good vigor, high yield and early maturation, but are also prone to cracking (Widyastuti, 1995:37). Gardner and Heider (1968:39) found that certain varieties were preferred for breakfast, others for workday snacks, and others for relaxed evening meals.

Women can also single out cultivars that need special cultural treatment, like staking of varieties that have long vines that would cover other cultivars and reduce root size (Schneider et al., 1993:41). There are other recognized variety-specific properties: the cultivar *Welayuk*, for example, easily rots and has to be harvested as soon as it reaches maturity (Widyastuti, 1995:37). Selection works first on the level of perception, and second on the level of utilization. In the end, it is the observation and selection by farmers that may eventually lead to establishing a new member of the cultivar inventory. Farmers, not researchers, are directing variety selection (Schneider, 1995c:67).

Heider (1969) was unable to find any evidence that the Dani name varieties due to variations in susceptibility to drought or flood or diseases (an insurance hypothesis). He was also unable to find any evidence to support a similar hypothesis related to different varieties variation in maturation time. However, later research has shown that maturation ranges from 90 to 240 days after planting and varies with altitude and cultivar, and first maturing cultivars are recognized by farmers (Schneider et al., 1993:41-2). Achmady (1988, cited in Schneider et al., 1993) breaks the 81 cultivars into 65 classified as "valley-bottom" and 16 as "hill- or slope-cultivars." The valley floor (52) and hillsides (26) each have their own set of specifically adapted cultivars, and this distinction is made by farmers, but this distinction accounts for less than half the cultivars collected (Schneider et al., 1993:41). Research by Achmady (1988:107, cited in Schneider et al., 1993) also produced a list of cultivars adapted to slope cultivation. Brookfield (1964:21) notes that some varieties in Chimbu (PNG) are grown only in specific localities, while others occur in gardens anywhere from 5,000 to 9,000 feet above sea level.

Tsunoda (1959; cited in Bourke, 1977:91) designated varieties of sweet potato as adapted to high, medium, or low optimum levels of fertilization. Bourke (1977:91) further notes that reports of yield reductions from fertilization, received occasionally from farmers, likely reflect the use of varieties adapted to low N conditions in these cases. Bourke (1977:94) concludes that fertilizer should be applied cautiously to varieties whose responsiveness to fertilizer is not known. Levett (1992:63) also found that cultivars from PNG differed in their sensitivity to weed competition.

3.3. Sweet Potato Nutritional Assessment

3.3.1. Crude Protein Content

The dry matter contents (21.7 - 41.5%) of tubers for 93 highland PNG cultivars analyzed by Goodbody (1984) fell within the range reported worldwide. Protein levels for New Guinea highland cultivars are generally rather low compared to the global reported range of 1.3 to >10% (Walter et al., 1984), especially compared to those reported by Selleck (1982; cited in Bradbury et al., 1984:471), 0.5-23% on a dry weight basis. Still, Goodbody (1984) found great variability in crude protein content among 93 sweet potato acquisitions from North Simbu in the highlands of PNG, ranging from 1.6 to 5.3 % on a dry matter basis (Table 5). It can also be assumed that great genetic variation in protein content exists in highland sweet potatoes from Irian Jaya, as Plarre's (1995:10) coefficients of variation indicate large variability (Table 5). The frequency distribution follows a normal curve, common for quantitative features influenced by genetic and environmental factors, suggesting great chance for improvement in protein content by selection. Bradbury et al., (1985) found variability in crude protein, trypsin inhibitor, and amino acids between roots from the same plant, across roots from different plants of the same cultivar, as well as between cultivars. Moreover, Bradbury et al. (1984:470) found that crude protein content of sweet potato skin is 50-90% higher than that of the bulk of the root. Plarre (1995) thinks that both protein quantity and quality can be improved in sweet potatoes by precise screening, noting that the composition of essential amino acids is more favorable in highland cultivars than lowland ones, although the total amount of protein is reduced (Oomen et al., 1961).

Popular highland sweet potato clones are low in protein, though there is considerable variation (Table 6). None reaches even half of the protein value of varieties with agricultural merit (8.0-9.4% crude protein on dry matter basis) from the Irian Jaya lowlands or imported strains (Oomen et al., 1961:58). However, protein contents of highland clones grown at lower altitude in the coastal plain were even lower. Moreover, the relative percentage of real protein in highland tubers (79-95%) is higher than in lowland tubers (67-76%). Harvesting sweet potato tubers at either six months or nine months after planting does not seem to affect protein content (Oomen et al., 1961:59).

In a study of sweet potato leaf tips as vegetables in the Philippines, Villareal et al. (1979) found considerably less variability among ten cultivars, but substantially more protein than in the tubers (18.0 - 21.5%). Significant differences were found for time of harvest and its interaction with the cultivar for both protein and dry matter, suggesting seasonal responses of particular cultivars.

3.3.2. Amino Acids and Other Nutritional Aspects

All 15 cultivars in Goodbody's (1984) study in highland PNG exhibited adequate essential amino acid patterns, with the exception of the sulfur-containing amino acids, especially cystine/cysteine. The review by Walter et al. (1984) confirms this finding more widely, noting that total sulfur is limiting, and in some cases lysine and/or tryptophan are also limiting. Bradbury et al., (1984:471) also found S-containing amino acids most often limiting, while noting that a range of different amino acids may be limiting. Bradbury et al. (1985) cast some doubt on all these findings, suggesting that lysine and leucine are most often limiting for PNG highland cultivars, with S-containing amino acids in third place. Goodbody also remarked on the generally high levels of tryptophan in highland cultivars, compared to lower levels reported in the US. From 60 to 85% of the nitrogen in sweet potato is proteinaceous, with a protein efficiency ratio (PER) equal to casein (milk protein) (Walter et al., 1984).

Oomen et al. (1961) found sodium content of highland tubers to be very small, but some coastal varieties contained about twenty times as much. Potassium is high, so perhaps sweet potato has a specific potassium affinity. The result is that the highlander consumes 200-400 times more potassium than sodium (suggested lower daily limit is 500 mg NaCl, but sweet potato diet contributes only about 75 mg). Calcium intake from sweet potato is considerable (500-1000 mg daily) (Oomen, 1961:62). Compared with other leafy vegetables, Villareal et al. (1979) found that sweet potato leaf tips have more vitamin B_2 and offer a good source of this vitamin that is generally deficient in Asian diets.

3.3.3. Trypsin Inhibitors

Sweet potatoes have been shown to contain trypsin inhibitors, findings which are of some concern because of the anti-nutritional activity of the inhibitors (Lin and Chen, 1980: Sugiura et al., 1973: both cited in Walter et al., 1984). However, Dickey and Collins (1984: cited in Walter et al., 1984) demonstrated that baking or boiling destroyed most of this inhibitory activity, thus associated nutritional problems for humans and/or pigs should only occur where roots are consumed raw. However, earlier research by Lawrence (1979:42) and others (Sugiura et al., 1973) suggested that inhibitors of trypsin are stable at the temperatures reached in the normal cooking in the highlands of PNG. Trypsin inhibitor has also been implicated in the onset of *Enteritis necroticans*, a sometimes fatal childhood disease in the PNG highlands known as pig-bel (Lawrence, 1979). Until recently, pig-bel was the main cause of death of children over one year of age (Lawrence et al., 1979; cited in Bradbury et al., 1984:469). Although there is now an effective vaccine, its ultimate efficacy is limited by its restricted delivery to populations at risk, at best only 50% of children (Lawrence et al., 1979; cited in Bradbury et al., 1984:469). The reasons why this disease is endemic in the highlands are diverse. The subnutritional condition of children, the large proportion of the diet provided by trypsin inhibitor-containing sweet potato, coupled with the sporadic consumption of protein-rich pork that is often repeatedly heated and cooled are all suspected factors (Lawrence, 1979). However, Bradbury et al. (1984:472) did not find that incidence of the disease was related to high trypsin inhibitor content of sweet potatoes; in fact, their results were in the opposite direction, though not significantly. The range of trypsin inhibitor across cultivars is very large, from 0.26 to 43.4 for the 10 varieties studied by Bradbury et al. (1985). These researchers also found no correlation between crude protein content and trypsin inhibitor content. They also found no correlation between the color of a cultivar's skin and/or flesh and crude protein or trypsin inhibitor.

3.3.4. Human Consumption of Sweet Potato

Kimber (1972, cited in Goodbody, 1984), concluded that in the highlands of PNG, sweet potato never provided < 50% of the diet, and could provide > 90%. Three surveys from the Sinasina area of Simbu Province, PNG, found sweet potato contributing between 53.2 and 70% of total energy, and between 34.2 and 69.1% of total protein (Hamilton, 1956: Harvey and Heywood, 1982: Lambert, 1976: all cited in Goodbody, 1984).

3.2.3.1. Dietary Status

Oomen et al. (1961:55) describe in some detail the dietary condition of highland Irianese. Total dependency on sweet potato leaves populations (particularly young children and lactating or pregnant women) vulnerable to food shortages and even famines during even short-term drought. Liver cirrhosis, a frequent disease of adults in at least one region, demonstrates the prevalence of protein malnutrition, as it is an indicator of dietary protein poverty. Often caloric intake is limited, but protein supply seems to be the most critical. The intake of ascorbic acid is usually high and carotene is satisfactory. A typical highland meal would consist of 1,500-2,000 g of tubers and 200-400 g of leafy vegetables. Per capita food intakes are likely somewhat higher than 1,500 calories, protein intakes may be extremely low (12-15 g daily), and fat intake practically non-existent (*Pandanus* fruits providing one of the very few sources of fat in their diets). Flannery (1998:228-9) underscores the importance of the palm-like mountain *Pandanus* fruit to the Dani people with vivid imagery:

The football-sized clusters of nuts they produce are by far the most highly esteemed plant crop the mountain people know. Smoked, they can keep for weeks or months. When the pandanus season comes, the Dani develop a single-minded obsession to gorge on the oily nuts. This has been referred to as 'pandanus madness' by some visitors.

Sunarto (1983: cited in Karafir, 1987) estimated average daily adult sweet potato consumption at 3kg. The Tim Survey Faperta Uncen (1986: cited in Karafir, 1987) estimated 2.89 kg/day for an adult male, 1.27 kg/day for an adult female, and 1.42 kg/day for children in the Paniai region. In Anggi, a family of three adults and two children consumed 7.5 kg/day of sweet potato (Karafir et al., 1984: cited in Karafir, 1987). In Kebar, Buyney (1982: cited in Karafir, 1987) estimated that adults consumed only 0.406 kg/day, and children only 0.271 kg/day, since it is a community with varied menu.

The differences in intakes between regions is more striking that any seasonal differences. Plarre (1995) estimates that about 80% of the calories consumed by the Mek people in the highlands of Irian Jaya is provided by sweet potatoes, 10% by taro and 10% by sugar cane. Oomen et al. (1961) state that the sweet potato accounts for 90% or more of caloric intake, about 75% of total protein intake, and the bulk of mineral constituents. Plarre (1995) also estimates that 75-80% of their daily protein comes from sweet potatoes, 10% from taro corms, and the rest from vegetables and small amounts of animal protein (including pig meat). Oomen (1961:333) claims that highlanders depend only on vegetable protein, except during rare pig slaughtering ceremonies. Schiefenhövel (1982:830) reports that the Eipo have an average daily intake of about 2.5 kg of mixed food (wet weight), with 1.5. kg being sweet potato and the rest sugar cane, vegetables and taro. He estimates that the sweet potatoes provide 1,250 calories/kg, for a daily average of 1,876 calories/day from sweet potatoes out of a total caloric intake of 2,505 calories. The crude protein content of the total food intake (mostly from vegetables) was calculated to be about 25 g/day/person.

In an interesting note on the nutritional aspects of sweet potato for human consumption, it is worthwhile to quote at length from the study by Bradbury et al. (1985):

"The fact that (1) the first limiting amino acid may vary even between roots from the same plant and (2) it varies between three different amino acids (leucine, lysine, and the S-containing amino acids) has important nutritional consequences. Thus, the well-known complementarity of amino acids that exists in a diet of rice (lysine limiting), combined with legumes (limiting in S-containing amino acids), is attained within a diet of sweet potato, because of the variability between the different roots. Clearly, the combination of a reasonably good chemical score (0.60-0.73) with internal compensation of three first limiting amino acids within different roots (even from the same plant) means that there is less imbalance of essential amino acids than is indicated from the chemical score. Unfortunately, the quantity of protein present in sweet potato (0.5-3% [fresh weight basis]) (and other tropical root crops) is greatly inferior to that of rice (~6%) and legumes (peas, beans)."

3.3.4.2. Malnutrition and Food Shortage

Although the morning and evening meals are monotonous, Heider (1970) claimed that there was never a shortage of food among the Dani. The tuber is practically never eaten raw but is either roasted in coals or steamed in a steam pit. The leaf of the young vine is also eaten steamed. When people work in the gardens during the day they usually take a baked sweet potato or two to eat cold. A number of people have gardens outside the immediate vicinity, and these are important as a source of sweet potato leaves, for the leaves from the neighborhood gardens cannot be eaten due to supernatural restrictions (Heider, 1970:39, 47, 61). Oomen (1961) claims that everywhere in the highlands sweet potato shoots are popular as a vegetable, but the relative deficits of the tuber protein are not compensated by the leaf protein.

Given the menu deficiencies, one would expect high incidence of nutritional pathology, but very little is superficially apparent. But perhaps high childhood mortality is connected with the meager diet (Oomen, 1961). In the Baliem valley, people tend to prefer sweet potatoes with soft texture and high water content, while adjacent mountain people like drier varieties that are sweeter (Widyastuti, 1995:37). Takagi (1987:155) reports a general preference in PNG for sweet and yellow-fleshed cultivars with dry texture. She further notes that in PNG, the flavor of orange-fleshed cultivars is not popular, thus the frequency of orange-fleshed cultivars is quite low. Only 19 out of 822 accessions (less than 2.5%) at Aiyura have orange flesh, and six of these are introduced germplasm. Takagi (1987:155) notes that this has nutritional significance, since β-carotene (provitamine A) is richest in deep orange-fleshed cultivars.

Lawrence (1979:41) notes that although clinical malnutrition is not common, subnutrition is; children are small for their age but will grow faster if their diet is supplemented. Lawrence (1979:46) claims that the trouble with sweet potato is that it forms such a large proportion of the diet; thus, people have a steady intake of trypsin inhibitor with a very low protein diet.

3.3.5. Sweet Potato as Pig Feed

In PNG, it has been estimated that 40% of sweet potato production is fed to pigs (Hadfield, 1978; cited in Sowei, 1993:79). Nonetheless, according to Rose and White (1980), references on sweet potato as a pig feed are few (Zarate, 1956; Calder, 196; Pond and Maner, 1974; all cited in Rose and White, 1980). Zarate (1956; cited in Rose and White, 1980) notes a difference between breeds in the ability to digest the sweet potato. Moreover, Zarate (1956, cited in Malynicz and Nad, 1973) found that sweet potato foliage digestibility is considerably lower than that of the tubers, due to a much higher level of crude fiber in the leaves and stems. Malynicz and Nad (1973) found that feeding of sweet potato vines did not significantly affect pig performance, but in fact it did adversely affect both live weight gain and food conversion ratio.

Analyses conducted by Rose and White (1980), show one PNG sweet potato variety with 34.8% dry matter, and 2.54% crude protein on dry matter basis. They report on mean intake and apparent digestibility by village pigs of dry matter (95.3%), organic matter (96.1%), energy (94.2%) and acid detergent fibre (72.4%). The digestibility of crude protein was significantly different ($P<0.05$) measured with two groups of pigs of different ages (57.2% for 15-month-old pigs and 42.3% for 10-month-old pigs). Dry matter intake for the older pigs of mean live weight of 92.9 kg was 925 g/day, while the younger pigs with mean live weight of 29.0 kg was 447 g/day. With levels of digestibility as high as these, Rose and White (1980) think it unlikely that cooking tubers will bring about any significant gains, a view supported by Calder (1960, cited in Rose and White, 1980). However, they concede that cooking the tubers may bring about significant gains in the amount that a pig might consume at any one time, if it makes them more palatable. If the cooked material could be ingested as quickly as the uncooked, then increased growth rates might be possible. Malynicz and Nad (1973) doubled consumption of sweet potato by European pigs by cooking it. This increased intake resulted in 36% more live weight gain but a 29% reduction in the food conversion ratio.

3.4. Diseases, Pests and Natural/Manmade Disasters

3.4.1. Diseases and Pests

Magee (1954; cited in Van Velsen, 1967:126) found sweet potato in the Territory of Papua and New Guinea to be free of virus diseases. Prain et al. (1995:711) claim that, at least for Manokwari and Anggi, there are no major pests or diseases to which varieties may differentially respond. The level of sweet potato pests and diseases encountered by Schneider et al. (1993:24-6) was also generally low. However, Floyd et al. (1988:2) claim that survey and experimentation have shown that diseases and pests, particularly nematodes, may be important constraints to yield in

PNG. Van Velsen (1967) describes a "little leaf" virus from PNG, with vein-clearing symptoms, that greatly reduced yield of sweet potato when infected in the early stages of growth. Apparently this condition is caused by a mycoplasma-like organism (Pearson, 1981, 1982: cited in Bourke 1985a:98, 100). Even rogueing of infected plants in the field had little effect as a control measure. Both Takagi (1987) and Bourke (1985a) review some of the many pests and diseases that have been recorded in PNG. These reviews indicate that the sweet potato weevil (*Cylas formicarius*) can be a major problem, but usually it is only serious in areas with a marked dry season or in very dry years. Control measures include crop rotation and use of uninfested planting material (Kimber, 1972; Smee, 1965; Sutherland, 1982; all cited in Bourke, 1985a:98). Sweet potato leaf minor (*Bedellia somulentella*), hawk moth (*Agrius convolvuli*), vine borer (*Omphisia anastomosalis*) and other occasional insect pests have all been recorded. Sweet potato scab (*Elsinoe batatas*) is common in PNG, causing most damage in the highlands. Leafspot (*Cercospora timorensis*) has been frequently reported, though its economic significance is unknown. Bourke (1985a:100) reports that sweet potato yields have been severely reduced in some areas in the past due to nematodes and the fungus *Fusarium oxysporum*.

A number of varieties appear to be more susceptible to the scab disease than others: therefore, a variety of mixtures is likely to help control the disease. Sowei (1993:80) notes that in some PNG evaluation trials, varieties of sweet potatoes were assessed for their resistance to scab disease and weevil, suggesting some level of genetic variability in resistance to disease and pests. However, evaluations of weevil resistance have yet to find a stable source of resistance. At least one PNG cultivar has been found resistant to vine borer, and the majority of PNG accessions have proved resistant to root-knot nematode damage (Takagi, 1987:154).

In addition to diseases and insects, both rats and pigs (domestic and wild) can do much damage to sweet potato crops in PNG, and presumably Irian Jaya. Bourke (1985a:98) notes that turning the vines to expose the soil to the sun hardens it and helps reduce rat damage. Throughout New Guinea, most gardens are fenced off in one manner or another to prevent unwanted pig routing.

3.4.2. Frost

According to Schneider et al. (1993:25), the most serious risk to sweet potatoes is killing frosts (Lani, *aurakane*), especially at a place like Kuywage at 2,700 m, the apparent altitudinal limit for sweet potato growing in Irian Jaya. However, the western Dani (between the Baliem valley and Ilaga) are reported to cultivate *Solanum tuberosum* (Irish potato) above 3,000 m; a few sweet potatoes are also grown but yield poorly in this cold climate (Mitton, 1983; cited in Brookfield and Allen, 1989:201). Elsewhere, notably in the Chimbu valley of PNG, cultivation has attained a reported altitude of 2,850 m (Brookfield and Allen, 1989:205). Frost kills the above-ground growth of almost all crops grown in the New Guinea highlands. Sweet potatoes can recover if frost occurs before bulking of the tubers, but maturity is then delayed by several months; frost during and after this bulking phase creates watery and inedible tubers which quickly rot (Wohl et al., 1982; Bourke, 1988;1989; all cited in Brookfield and Allen, 1989). The latter authors note that important parts of the main belt of dense habitation between 1,400 and 2,850 m across New Guinea are subject to occasional ground frost.

Other natural and/or manmade hazards or risks, according to Schneider et al. (1993) include severe drought, flooding (Lani, *nyokeraki*) and heavy rains, hail (Lani, *mayu-kumilingen*), and the possible consequences of global warming (Brookfield, 1991:203,208).

3.4.3. Drought

Brookfield and Allen (1989:206) describe how most major drought events of regional scale affecting New Guinea in the past century have been in some way related to El Niño/Southern Oscillation (ENSO) events. Ballard (2000) describes how ENSO-related drought events have had severe impacts on Irian Jaya in 1914/15, 1941/42, 1972, 1982 and 1997/98. At the height of the drought in 1997/98, about 25% of Irian Jaya's population suffered from significant food and water shortages. Impacts included frosts in August 1997 above 2,220 m resulting in loss of 50-75% of the sweet potato crop at Ilaga at 2,450 m (Larson cited in Ballard, 2000). Residents were forced to resort to eating a secondary crop of Irish potatoes, regarded in this area as only fit for pig feed. At 2,700 m, in the Agadugme area of the Upper West Baliem valley, frosts destroyed the entire standing crop. The third area hit by frost was Kwiyawagi at 2,680 m. Even at lower altitudes sweet potato production was dramatically reduced. In Jayawijaya Regency, a crop survey at a range of altitudes found that 60-80% of the sweet potato had been severely affected by drought. The same survey team reported sweet potato scab fungus incidence as high as 70%. Moreover, large areas of gardens, secondary and even primary forest were destroyed by fire during the drought.

3.4.4. Flooding, Heavy Rain, and ENSO Events

Ballard (2000) also notes that La Niña-related wet events appear to be at least as significant as drought events in terms of disruption of the food supply. Floods can sometimes cause periodic devastation and famine along the Baliem River, but groups like the Dani with both bottom land and slope gardens do not seem to have a threatened food supply (Heider, 1970:9). Nevertheless, Bourke (1988;1989; cited in Brookfield and Allen, 1989:208) argues that the most widespread cause of poor sweet potato performance in the highlands is neither frost nor drought, but rather spells of exceptionally heavy rain, especially during the weeks following planting when tuber growth is initiated. Bourke (1989; cited in Brookfield, 1991:209) has shown that soil water logging inhibits tuber growth in sweet potato, and when followed by drought the surviving tubers are small. The sequence of an extended period of water surplus followed by drought is in turn frequently followed by food shortage (Brookfield and Allen, 1989:208). Therefore, the juxtaposition of warm and cold events becomes an element in the total hazard (Van Loon and Shea, 1985; cited in Brookfield and Allen, 1989:208). Brookfield (1991:209) infers that the highland crop economy is therefore sensitive to prolonged departures from the "normal" Southern Oscillation conditions.

3.4.5. Low Temperature and Cloud Cover

In areas of heavy rainfall, like the Wissel Lakes, weeds can be problematic (Brookfield, 1964:24-5). Brookfield (1964) argues that in the humid and cloudy highlands of New Guinea, it is only locally that frost is the compelling limit to the upward advance of settlement; more generally, it is a problem of the level of cloud formation. Not only persistent moisture, but also lack of sunshine and warmth limit agriculture in the clouded regions. There is virtually no agriculture in areas with heavy and persistent cloud cover on the ground, even where this is as low as 3,000 feet (914 m). But Brookfield (1964) agrees that frost has the most obvious detrimental effect on sweet potatoes. Drought, often associated with frost, also creates stress, and when it occurs during the bulking period it may delay maturity or reduce yield of sweet potatoes (Brookfield and Allen, 1989:207). Brookfield (1964) also notes that more generally, low temperatures retard sweet potato growth. On good soils at 5-6,000 feet (1,524 to 1,829 m) tubers mature three to five months after planting, but above 7,000 feet (2,134 m) they take from eight to twelve months. Brookfield (1964:28) blames widespread frosts combined with prolonged sunshine in the highlands, resulting in extremes in ground temperatures and unusually low relative humidity, for the most severe conditions for plants. At noon, when relative humidity drops to 50% or so, the soil becomes much warmer than the surrounding air, resulting in rapid evaporation accentuated by dry southeasterly winds. All this results in diurnal fluctuation and day-to-day variation. The most significant climatic variables for sweet potatoes are minimum temperature, relative humidity, cloud cover and rainfall.

3.4.6. Sweet Potato Adaptations to Environmental Stress

The wide range of ecological conditions where sweet potato is grown reflects the enormous adaptability of the plant and its wide genetic diversity throughout New Guinea. There appears, therefore, to be a certain degree of adaptations to these various environmental stresses. Of 14 accessions identified by AVRDC (1984; cited in Takagi, 1987:153) as moisture-tolerant, eleven were from PNG. Among the 54 varieties from PNG evaluated for drought tolerance by Levette et al. (1985; cited in Takagi, 1987:153), five varieties were selected on the basis of consistently high yield. Finally, cultivars from both the PNG highlands and the Andean region all showed consistently good low-temperature tolerance (Yen, 1974; cited in Takagi, 1987:153).

3.5. Socio-Cultural Significance of Sweet Potato

3.5.1. Ritual Traditions

With almost total reliance on the sweet potato for human consumption and pig feed, it is no wonder that cultivation of the plant takes on a certain ritual significance in highland cultures. Heider (1970:42-3) discusses several ceremonial activities related to sweet potato garden magic, including a "ghost bridge," cave-in knots, and garden arches that serve as a home (*ai*) for the soul, or essence (*akotakun*) of the sweet potato which is about to be planted. If the *akotakun* has no home, the sweet potatoes do not grow. Also, near the garden arch, a mound is prepared and planted with many sweet potato cuttings before the new gardens are planted. Later these tubers, called *hibiti juguk,* are steamed and eaten by men, women and pigs. Similarly, the *gapura kebun* is a symbolic house for the sweet potato spirit (*agot-agut* in Dani) built in the middle of the garden (Schneider et al., 1993). Among the locations studied by Schneider et al. (1993:30), the Dani community of Kimbim most fervently maintains the ritual traditions related to sweet potato cultivation.

Sweet potatoes can normally be clearly traced as the property of one man or woman from planting right up to consumption, but are offered to whomever happens to be present in a compound at mealtime (Heider, 1970:24). Particularly large tubers, weighing as much as two kg, are primarily eaten at ceremonies. Vines growing in the immediate vicinity of the Dani are taboo (*wusa*), and cannot be eaten. The leaves that are eaten come from gardens outside the immediate vicinity (Heider, 1970:31).

3.5.2. Gender and Labor

Three stages of the garden cycle are done exclusively by men (Heider, 1970:39):

- chopping the heavier trees and shrubs in clearing (using the adze)
- fence building (using the adze, rarely handled by women)
- digging and maintenance of the ditches, including mudding (women never enter the ditches, apparently it is taboo)

Men tend to do heavy garden work like breaking the soil with the heavy digging stick, while women usually use their own lighter digging sticks to plant (theoretically only done by women, but men often also plant), weed, thin the vines by trimming off the ends of the vine creepers, and harvest (the latter is the only task done exclusively by women) (Heider, 1970). However there is variation in the labor division between men and women among kinship groups and village communities. For instance, in Tiom each man has from one to five beds of sweet potato, excluding cultivars used as baby food or pig feed (Schneider et al., 1993). When a man has broken the soil of the garden, and just before or after planting, the garden is smeared with mud and organic matter from the adjacent ditches. This is usually done by a work crew (*jogo*) summoned by the man (Heider, 1970:39).

4. Pig Production and Use

The management system for pig production in the highlands of New Guinea is extensive, as pigs are let out in the morning and allowed to wander during the day, grazing forest areas and fallow fields, and penned at night, with feeding of sweet potatoes. However, productivity and performance are poor, with small litter sizes averaging four reared and growth rates of 75 g/day common (Densley et al., 1977 cited in Walters, 1981:275).

4.1. Types of Pigs in New Guinea

4.1.1. Village Pigs

Village pigs in Papua New Guinea are *Sus scrofa papuensis* (Rose, 1981). The general term for pig in Dani is *wam*. According to Hedier (1970:55), there are no feral pigs at all in the Grand Valley. Pigs are distinguished in terms of color (Heider, 1970):

- *modla*, or light-skinned pigs
- *mili*, which are dark or black pigs
- *bima*, fairly rare pigs which are generally reddish-brown, but laterally striped like a chipmunk when young, fading with age
- *dakabe*, or spotted black and white pigs
- *wilehasu*, which are dark pigs with white bellies

4.1.2. Introduced Breeds

In a Dutch book called “Het verdwenen volk” (the lost people), Dr. J. V. de Bruijn states that a few white skinned European breed boars (no breed specified) were introduced in the highlands (Lake Paniai area) in 1939 (Couprie, pers. comm.). Average litter size grew from average 3-5 to 7-10 piglets (Couprie, pers. comm.). De Bruijn, the Dutch government worker who as a Dutch civil servant opened up part of the highlands in the lake Paniai area, later states in the book that in 1956 all white pigs in part of the same lake area were killed during a local uprising (Couprie, pers comm.). According to Ryan (1969:187, cited in Aditjondro, 1982), however, the Dutch introduced European pigs in West Irian in 1956. Ryan (1969:356, cited in Aditjondro, 1982) also states that the Indonesians imported Australian Berkshires and Large Whites from Australia via PNG into Irian Jaya in 1969. Hedier (1970) also confirms that in the 1960s, large boars of better meat-bearing stock were flown into the Grand valley by government and missionary groups and strategically distributed to the Dani. Because of selective castrations, Heider (1970:51) predicted that these boars would have a rapid effect on the quality of the Grand valley pig population.

4.1.3. Demographics of Pigs

Demographic studies of pigs in the Highlands of PNG have reported populations of (all cited in Rose, 1981):

- 0.88 to 2.1 pigs per capita in the Goroka, Simbu and Hagen areas (Malynicz, 1976 or 1977)
- 0.27 to 0.89 pigs per capita in Simbu (Hide, unpublished data)
- 1.1 to 5.6 pigs per woman in the Tari area (Rose, unpublished data)

4.2. Pig Husbandry

4.2.1. Daily Routine

According to Heider (1970), all the pigs of a single household are kept together in a single herd, live in the same pig sty, and are driven out together. Pigs spend the night in stalls in the compound sty, and each has its own stall, except for unweaned shoats and small litter mates. In the morning, pigs are let out into the yard where they scrounge until driven to the current rooting place. If raining or ceremony, pigs are not driven but let out briefly to defecate. They also defecate in the courtyard but rarely in the sty itself. In the field or woods, they root for several hours, until afternoon when they are herded back to the compound. By dusk they are put back in the stalls and given a few kilos of the smallest sweet potatoes (Heider, 1970:49). In some areas, like in Chimbu (PNG), all cultivated land is within fences, and pigs graze in the unenclosed areas (Brookfield, 1964:35). In Paniai and Anggi, Karafir (1987:320) reports that before sweet potato fields are left fallow, pigs are released into the gardens. In rooting for leftover tubers, the pigs till the soil. Often Dani men will dig holes in paths 50cm deep and a meter long which fill with water during wet periods for pigs to wallow in them (Heider, 1970:50).

4.2.2. Local Practices

The ears of pigs are usually cut to help the pigs grow, according to local belief. Heider (1970:50), describes four different patterns of ear cutting. The patterns are not unique owners' marks but do help identify the pigs. Most male pigs a few weeks old are castrated to make the pig grow larger and produce large tusks, to keep it from running after female pigs, and to remove it from the breeding pool. This is done with a bamboo knife, and bamboo splints pin the scrotum together. Sometimes ashes are sprinkled on the wounds (Heider, 1970:50). The Dani practice selective breeding, and only the largest and most promising shoats are not castrated (Heider, 1970:51). Another operation is performed on the bellies of female pigs after they have been weaned, again allegedly to make them grow larger (Heider, 1970:51).

4.3. Feeding Techniques

When sweet potato harvesting is finished, pigs are often let run in the gardens to eat the remaining small tubers. These may be the pigs of the user of the garden or, if agreed upon, the pigs of someone else (Heider, 1970:40). In some highland areas, pigs are tethered by the foreleg, as is the local custom near Goroka (PNG), with a short rope held by a short stake stuck in the ground at the side of a sweet potato mound (Rose, 1981).

Usually sweet potatoes are baked, but sometimes also boiled for pig consumption. In Kimbim, pigs are fed raw tubers, not cooked ones like in other places (Schneider et al., 1993:33-4). If a sow is killed before the shoats are fully weaned, a woman takes charge and feeds them pre-chewed sweet potato (Heider, 1970:51). In the Vokelkop (Bird's head) region of Irian Jaya, McNeely and Sochaczewski, (1988:174) were startled to see a woman suckling a baby pig at her breast. When the piglet had finished, the woman's year-old daughter took her turn. However, during Heider's (1970:51) field work among the Dani, this practice was not observed and all informants denied it emphatically.

4.4. Dietary Intake of Pigs

Pigs fed under village conditions in PNG may gain only 50 g body weight per day when intake includes nutritiously poor grazing of sweet potato fallow (Rose and White, 1980). The main observation of trials conducted by Rose (1981) is that pigs can grow relatively well with a small amount of hand - fed protein. The capacity of the ground to produce earthworms would seem to be important in increasing the liveweight gains of foraging pigs. Since the protein content is so low in a tuber diet, the protein available from soil fauna is of considerable value in the nutrition of village pigs in the highlands (Rose, 1981). A feeding system developed by Lehmann in

Germany at the turn of the century is based on the knowledge that pigs eat for energy not for protein, so as the pigs grows their requirement for energy increases and they consume more sweet potatoes, but protein requirement stays at about the same level. Therefore, according to Watt (1973), 454 g of concentrate per day is sufficient regardless of age or size, except lactating sows need 908 g per day. Table 7 reports on average daily live weight gain of pigs under various conditions and diets in Papua New Guinea.

4.5. Health and Disease of Pigs

According to McNeely and Sochaczewski (1988:176-7), when the United Nations sponsored the West New Guinea vote on independence, President Suharto instructed soldiers to take a gift of pigs from Bali to give to the Ekari people. The gift pigs carried tapeworm, which according to Desowitz (1983, cited in McNeely and Sochaczewski, 1988:177) had been endemic in Bali for at least 60 years. "Once the Balinese pigs reached highland Irian Jaya, where pork is barely cooked and toilet habits are the most basic, the people quickly became infected. The outbreak of pig tapeworm disease (cysticerosis) became known when, in 1971, a bewildering epidemic of severe burn cases was reported among the Ekari…While sleeping, they had been overcome by an epileptic seizure and had fallen unconscious into the household fire." Tapeworm, killed relatively easy by refrigeration or cooking, was not applicable to the Ekari who kill their pigs in secret at night and throw them on the fire just long enough to warm them up and not wake the neighbors, with whom they do not wish to share the meat. A health educator was sent from Jakarta to demonstrate improved cooking practices, but the Ekari chief was bitter that the disease introduced by foreigners had corrupted the tribes' pigs and religion. He told Desowitz (1983, cited in McNeely and Sochaczewski, 1988:177), "We can see the seeds that give us the illness in the pig flesh. But no one lives forever and if we must die, then we must die. Life is no longer of pleasure. We are only half men. The Indonesians will not let us make the warfare that gave us manhood. I no longer care if I eat the corrupt pig flesh…When the missionaries brought us the coughing sickness many years ago [a pertussis epidemic in 1956], we rose in anger. This time we have no heart to do so." Aditjondro (1982) also cites the May 20, 1978 issue of the Dutch paper *De Telegraaf*, with a story of Indonesia airlifting thousands of pigs carrying a strange killing disease to the densely populated central highlands of Irian Jaya. According to Indonesian studies, the disease (epilepsy) was discovered to have been caused by cysts of tapeworms in the meat, which had not been thoroughly cooked by traditional means. However, Aditjondro (1982:65) calls into the question the origin of the disease, citing a publication by John Ryan (1969, cited in Aditjondro, 1982) that states that the "bush pig" was the source of the disease he called "Pig-Bel." Ryan apparently based his argument on claims that if outside pigs introduced the disease, then it should have appeared when the Dutch brought in European pigs to West Irian in 1956 (Ryan, 1969:187, cited in Aditjondro, 1982).

Note, however, that Cargill (pers. comm.) does not feel that the information, or at least the assumptions, in some of these articles is accurate. He states that it is true that most pig diseases are introduced by bringing infected pigs into a region or onto a farm. However, if pigs do not have the disease in the first place, then they cannot introduce the disease. So he claims that it does not follow that just because pigs were introduced that they should have brought the disease. This would only happen if they came from an area where the disease was present. Also, Cargill (pers. comm.) notes that "pig-bel" and *Cysticercosis* (the tape worm cysts referred to) are totally different diseases. "Pig-bel" is a bacterial infection which results when humans eat large amounts of sweet potato along with pork infected with a Clostridial bacteria. The sweet potato sets up a fermentation chamber in the stomach for the bacteria to grow in. *Cysticercosis* is caused by eating the tape worm cysts in undercooked pork.

More generally, the chronic ailment of pigs is sores (raw but not bleeding) in the skin from rodent bites at night. These are treated by plastering *Araucaria* pitch over the wound and then sprinkling the pitch with ashes from the fire (Heider, 1970:50).

4.6. Nutritional Assessment of Pigs/Pork in Local Diets

Among the Dani, as Rappaport (1968:62) has suggested for the Maring in PNG, "although pigs convert carbohydrates into valuable protein and fat, their total contribution of energy to men is less than the energy men expend in raising the pigs in the first place" (Heider, 1970: 48). Although domestic pigs regularly forage in the wild, pigs are also fed sweet potatoes (and in some places yams). Since an adult pig weighs more than an adult man, a woman has to work harder to feed an adult pig than to feed her husband (McNeely and Sochaczewski, 1988:175). Gardner and Heider (1968:41) concur that pigs have only minor significance as a source of nourishment in Dani diet. The most obvious use of pigs is as food (Heider, 1970). But Oomen (1961) claims that pigs are only killed on ceremonial occasions as infrequently as once a year, then people gorge themselves on meat for a few days. Moreover, Oomen (1961) notes that women get even less meat, thus less protein, than the men, and this is obvious in the striking contrast between physiques of man and wife. It is obvious from Matthiessen's (1962) account of traditional Dani life, that women received considerably less pork, thus protein, than the men. However, the sacrificing of pigs in the life of the Dani described by Matthiessen (1962), and thus the consumption of pork, occurs with surprising frequency. Smith (1979; cited in Lawrence, 1979:46) found that in Tari, PNG, eating pork for most of the population was a once a week occasion. Lawrence (1979:46-7) then notes that infrequent meat-containing meals would contribute less nutritionally than more frequent consumption of the same total amount.

Interestingly, in Eipo society, the flow of protein is channeled towards the women and small children (ages four to 10) by virtue of their gathering and consuming insects, reptiles, eggs and larvae, adding perhaps five g/day of additional protein (Schiefenhövel, 1982:830-1). It is important to note that Eipo society is an anomaly among Melanesian highland cultures in that about one third of the population (in the mid-seventies, prior to acculturation from outside) of the southern Eipomek valley was barred from consumption of pork due to taboos. A mythological pig is considered an ancestor by several clans who therefore must refrain from eating pork (Schiefenhövel, 1982:831).

4.7. Significance of Pigs in Local Economies and Cultures

4.7.1. Economic Significance of Pigs

The island of New Guinea is the pig center of the world. Men value their wealth in pigs first and wives second, and the four-legged possession can be worth more that the two-legged one (McNeely and Sochaczewski, 1988:174). Wives and wealth are directly related in polygamous families: the more wives, the bigger garden area, the higher production, and the number of pigs (Schneider et al., 1993:21). To consider pigs only in terms of their nutritional contribution to the Dani is to miss the total impact of pigs on Dani life (Heider, 1970:48). Pigs enjoy a protected status in Dani society, because they are important in economic terms (Gardner and Heider, 1968:41). Those areas in the highlands that do not have the trade advantages of quarry, forest, or brine, must rely on pigs for their trade items (Heider, 1970:26).

4.7.2. Socio-Cultural Significance of Pigs

According to Gardner and Heider (1968:41) raising pigs has a fascination and importance almost unequaled by any other activity among the Dani. The Dani consider pigs the most important living creature besides people. Pigs equate to wealth and social importance, and to own a large herd is the most desirable of all goals. While ownership and use of pigs is a male prerogative, their care belongs to women and children. A man is as interested in having wives and children to look after pigs as he is in having pigs in order to afford wives and children. A man only bothers himself with the most important pig decisions, like which are to be offered at a funeral, which are to be fattened and given away for a periodic ceremony, and which are to be donated to a child or wife as too small or orphaned. A man also supervises the breeding and castrates all but the best males. But women and children are closest to the pigs on a day-to-day basis. By the age of ten, children may be given the care of household pigs. Negligence during pig herding is a major cause of friction between parents and children (Heider, 1970:24, 50). Pigs are basic to Dani culture (Heider, 1970:48). Traditionally, unless a pig dies accidentally or of sudden disease, pigs are saved for ceremonial purposes. Most Dani ceremonies are symbolic statements communicating to the ghosts the concern of the living for the dead (Heider, 1970:52). The only nonutilitarian parts of the pig are the gall bladder, the bristles, and bones too large to be chewed and eaten and not otherwise turned into implements.

Many cultural interactions involve payment of pigs, often in the form of reciprocal obligations (Schneider et al., 1993). Gardner and Heider (1968:42) claim that civil order in Dani society is maintained by a balance between the strength of arms and traditional payments in pigs or other wealth. The breeding rate of pigs in PNG determines when the women get a break from housework and the men go to war (McNeely and Sochaczewski, 1988:6). The great pig festivals that traditionally take place about once every five years are described as the renewal of fertility on which the success of subsistence activities hinges. The ritual involves the mass slaughter of pigs, and sacral objects (*kanneke* in Dani) such as pig bones, stone blades, sweet potato tubers, and the blood from a slaughtered pig (Verheyen, 1971; Boelaars 1986, quoted in Schneider et al. 1993:16). In numerous highland societies, pigs or parts of pigs are accorded an almost sacred aspect. Among the Eipo described by

Schiefenhovel (1982:837), *fuana* is considered the most powerful treatment or curing ritual, in which a piece of sacred fat (*yudena* and other terms) is taken from a pig belly and repeatedly rubbed on the skin of the patient and pulled off with a jerking motion, while the healer chants.

Among the Maring people of the Bismarck Mountains of PNG, anthropologist Marvin Harris wrote in *Cows, Pigs, War and Witches* (cited in McNeely and Sochaczewski, 1988:174): "In the ambience of pig love one cannot truly be human except in the company of pigs. Pig love includes raising pigs to be a member of the family, sleeping next to them, talking to them, stroking and fondling them, calling them by name, leading them on a leash to the fields, weeping when they fall sick." In fact, the respected spirit of the pig joins the spirits of the humans when the pig is sacrificed and eaten.

5. Current Status of Integrated Systems Research

Archeological studies like those summarized by Golson (1997:46-7), suggest that the critical period when environment, agriculture, pig husbandry, and exchange assumed features recognizable in the ethnographic record falls between 2,000 and 1,000 years ago. Working in PNG, Sowei (1993:79) remarked that the build up of the pig population could be regarded as a form of storage into which surplus sweet potato is placed until required, in other words when the pig population competes for food with people. While it is evident that life in the highlands of Irian Jaya revolves around sweet potatoes and pigs, there has to date been little integrated research linking the components of the humans-sweet potatoes-pigs system. Even that which is published on systems approaches to sweet potato research (Figure 1), does not integrate the pig component of Irianese agricultural systems.

Working in PNG, Kimber (1982) notes that as more pig projects develop, pig dung will become easy to obtain and cheap, and could help increase sweet potato yields and gradually improve soil. In many farming systems, a mixture of pig dung and urine is returned to the field. However, in PNG the use of both pig dung and urine is rare. Some farmers may wish to sun-dry the dung before using to make it lighter and easier to carry.

An experiment at Goroka, PNG, showed that pig dung as fertilizer for sweet potato can increase yields. There were three treatments as follows (Kimber, 1982):

Treatment	Yield (kg/ha)
No dung	13,400
22 t/ha	17,000
44 t/ha	15,900

Kimber claims that the larger amount of dung may have been too moist and hot. In fact, an editorial note in the same paper states that "Aiyura staff in the Southern Highlands Province" conducted further experiments and found that 15 t/ha was recommended for increased sweet potato yields. Kimber (1982) concludes that small farmers should be encouraged to use pig dung for its short-term and long-term benefits. Villareal et al. (1979) also found that application of 120 kg N/ha gave higher sweet potato tip yields than no nitrogen through an increase in number and size. Frequency of harvesting did not influence yield.

After WWII, PNG introduced new breeds of pigs, continuing through the 50s and 60s, but by the 70s it was clear that this distribution program had not increased performance to desired levels because of poor management and disease (pneumonia, anthrax and intestinal parasites. So emphasis shifted to improving management, housing and feeding systems, including training and extension, housing designs using local materials, and rations based on a fixed amount of protein with sweet potato fed ad libitum. A series of smallholder 2-sow breeder/fattening units were set up, but by the 80s these were largely defunct due to problems with maintaining a continuous supply of feedstuffs (Malynicz and Asare, 1976 cited in Walters, 1981:275).

6. Implications for Future Research

The following discussion of implications for future research combines observations from both Irian Jaya and PNG, but makes every attempt to flag those that have come from experiences in PNG. Much of the work done to date, especially that in PNG, has been on experimental research stations. There is a general lack of experimental work conducted on-farm, and so the current project's on-farm focus does appear warranted. Furthermore, Brookfield (1964:20) reminds us that with cultural ecology, regional generalization (e.g., highlands of New Guinea) requires great care, a wealth of data, and extraordinary powers of vision. Project personnel must cautiously evaluate conditions and conclusions from other geographical and cultural areas of New Guinea for relevance to the local situation.

6.1. Socio-Cultural Context

Most extant descriptive literature on sweet potato cultivation and pig husbandry systems in Irian Jaya has resulted from the work of anthropologists like Heider during the 1960s. In light of rapid and dramatic changes over the past 40 years, it would be most fascinating, and perhaps valuable, to begin to compare contemporary systems and practices with those reported in the seminal anthropological literature. Additionally, the review of relevant literature suggests a number of considerations related to the socio-cultural context in which the present research is to be conducted:

6.1.1. Language and Culture

0. Schneider et al. (1993:36) state that it is not uncommon for Dani to feel threatened if outsiders try to elicit much information about the semantics and symbolism of their culture.

1. Language is also a problem in Irian Jaya, particularly with older people. Widyastuti (1995:40) suggests patience and the use of a translator. She notes that the concept of growth period (months to harvest) can cause confusion, as many people are not used to counting the months or seeing their crops in an absolute time continuum. She also suggests distribution of small gifts (tobacco, cigarettes, candies or salt) to make things smoother during interviews.

2. The obvious implication of the above observations is that considerable care must be taken when dealing with local people, whether as informants or as collaborators in on-farm trials. Attention must also be given to the potential for a language barrier: therefore, the project's intent to work through local Dani professionals seems well considered.

3. There is considerable inconsistency in the literature when it comes to the use of Dani-language terms, and this can lead to potential confusion and misunderstanding between project personnel and local Dani people, and even among project personnel. Schneider (pers. comm.) is not aware of the existence of a standard Dani dictionary against which to check the spelling of various terms, but project personnel may wish to follow up on this and see if such a dictionary does exist. At the very least, project personnel should be aware of this variation in terminology, and to the extent possible makes attempts in project writing to use consistent terminology.

6.1.2. Indigenous Knowledge

4. Prain et al. (1995:696) note that the assiduous cultivation of sweet potato diversity in Irian Jaya reflects a sophisticated knowledge of the crop which has evolved with the germplasm. Unfortunately, like the germplasm itself, this knowledge is in danger of disappearing as new varieties and technologies are introduced. They note, therefore, the urgent need for conservation of both, something to which the project's interdisciplinary team is well situated for contributing.

5. Prain et al. (1995:699) found that individual interviews were not initially satisfactory in their research, partly due to the fact that they were taken first to local political leaders, not necessarily the real sweet potato experts. They note that while obligations to these local leaders must be honored, care should be taken that they do not derail the search for local expertise.

6. Another issue that needs attention and should be incorporated into future work on understanding indigenous knowledge about sweet potato is that non-technical knowledge, such as farmers' preferences, decision making processes, sweet potato status in relation to other crops, and socio-cultural values of sweet potato have not been intensively researched (Matanubun et al., 1995:60)

7. Research is still focused too much on the main production areas of sweet potatoes, but in fact sweet potato is cultivated in nearly all Irian Jaya ecosystems (Matanubun et al., 1995:60).

8. While the project will work mainly in one such area, the Baliem valley, it is important to cast a wide net in relation to the implications of its own results for other sweet potato growing areas of Irian Jaya (and PNG).

6.1.3. Gender

9. Numerous studies note the important role of women as repositories of expertise on sweet potatoes and their cultivation. It is not only essential to involve local women in this research and development project, but the presence of women in the research team can also help to ensure female input (Prain et al., 1995:697).

10. Widyastuti (1995:41) notes that elder males with high status, such as lineage chiefs, often possess "secret" knowledge that other people do not have in this regard, like the garden magician ("chief of fertility") in Kimbim and other tribal heads in Irian Jaya. This special knowledge may be related to the history of sweet potato in the area, the meaning of sweet potato names, and the origin of sweet potato. As noted above, it may be desirable to seek out such elder males with special knowledge as key informants for aspects of the present research. However, as Schneider (pers. comm.) notes, in the research endeavor, the balance should be kept in favor of women who in the majority of cases, hold the practical knowledge related to sweet potato cultivation and pig husbandry.

6.1.4. Ritual

11. The interaction of the Dani kinship system with agriculture (i.e., the kinship composition of Dani garden operations and their symbolic background) has not yet been studied (Schneider et al., 1993). To what extent the present project can consider these interactions is unknown, but the project does offer a significant opportunity for systematic and sustained observation and exploration of such relationships.

12. Heider (1970) and others describe certain types of garden magic ("ghost bridges," "cave-in knots," "garden arches" and "first fruits" (Dani *hibiti juguk*)), so it would be interesting to see what if any of these persists.

13. The great pig festivals that traditionally took place about once every five years were described as the renewal of fertility on which the success of subsistence activities hinges. The ritual involved the mass slaughter of pigs, and sacral objects (*kanneke* in Dani) such as pig bones, stone blades, sweet potato tubers, and the blood from a slaughtered pig. Schneider (pers. comm.) wonders to what extent this ritual is still staged today, so project personnel may wish to investigate this matter.

6.1.5. Social Land Organization

14. The process of adjustment to environmental detail emerges in the organization of land holding. Brookfield (1964:37) feels that it would be interesting to generate data on territorial organization in the Baliem valley, in the pattern of "drainage districts,' but unfortunately no study of this aspect has yet been conducted. Perhaps the project can begin to address this issue through community mapping exercises or other techniques.

15. Prain et al. (1995:698) found that the concept of "plot" that they used in their work corresponded to a rather complicated notion in Anggi, since rights of access to particular areas of land are determined by tribal affiliation, but ownership or use of particular gardens ("ro") is by household. It will be helpful for project personnel to bear in mind that similar discrepancies may appear in their work with farmers, and so the sooner information on land organization is elicited the better. Schneider (pers. comm.) concurs with the importance of this conclusion on the need for basic information on land organization.

6.2. Sweet Potato Cultivars, Cultivation, and Consumption

It is essential that the research work done so far be built upon by further research in order to benefit sweet potato growers. Globally, there appears to be considerable opportunity to increase protein content and quality through genetic selection and breeding, and manipulation of certain production and post-harvest handling practices (Walter et al., 1984).

6.2.1. Specific Research Needs in PNG

According to Bourke (1985a: 104), a number of specific research needs in PNG are apparent, though all but one apply as well to Irian Jaya:

16. Further breeding of new cultivars and evaluation of existing ones is needed. It appears that the project has anticipated this need.

17. A considerable amount of research work, especially at Aiyura in PNG, has not been collated into report form or published. This includes research on cultivars, fertilizers and growth analysis. Analysis and writing up of this work would be valuable. Perhaps project personnel can follow up with Bourke to determine whether this has been undertaken, and whether such reports, if any, are available.

18. Data on nematode, insect and disease problems are poor, especially on the economic significance of the various pests. Work is needed in this area, so perhaps the project will pay close attention to sweet potato pests and pathology by working with locals, entomologists and pathologists.

19. Knowledge of sweet potato in traditional farming systems is still inadequate. For example, little is known of crop and human responses to environmental stress such as excessive moisture and further research in this direction would be valuable. More implications concerning this need are raised in below.

6.2.2. Specific Research Needs in Irian Jaya

Achmady and Schneider (1995:76) suggest several measures to strengthen the role of sweet potato in Jayawijaya, all of which the current project may wish to bear in mind:

20. Integration of sweet potato into the programs for the development of secondary crops (e.g., trial experiments of a mixed crop of sweet potato and maize in farmers' fields).

21. Integration of aspects of sweet potato cultivation into the training of local agricultural extensionists.

22. Exploitation of agrotourism potential.

23. Community curatorship and on-farm conservation

6.2.3. Comparative Research Considerations

24. As the project undertakes various types of research and development activities, it should do so with an eye towards the value of comparative research. This consideration is all the more important in light of the fact that considerable research on sweet potato has been conducted in PNG, but very little in Irian Jaya. Therefore, the project should strive, wherever possible, to obtain data comparable to those already obtained in PNG. For instance, in the extensive fertilization trials on the Gazelle Peninsula of PNG (Bourke, 1977:75), tubers longer than 10 cm with a diameter over 5 cm were classed as saleable in some trials. In others, the critical size was reduced and tubers weighing more than 140 g were considered saleable, the latter classification approximating that used by local farmers. In yet other published trials, 100 g was used as the saleable weight, and even >60 g (and of reasonable shape) in another (Levett, 1992:64). At the very least, the project should make efforts to measure and report such variables as precisely as possible, keeping them comparable to PNG data where possible. Finally, Bourke (1977:92) also found that fertilization increased the proportion of saleable tubers in the PNG trials. He notes, therefore, that it is thus important to record the yield of saleable tubers as well as total tuber yield in such trials, so as not to underestimate the magnitude of fertilizer response.

6.2.4. Local Cultivar Identification, Documentation, Conservation and Improvement

If further work is to be done on the identification, conservation and replication of local sweet potato cultivars, observations from both PNG and Irian Jaya should be heeded.

6.2.4.1. Language and Cultivar Names

25. Heider (1969) found considerable inconsistency between informants on cultivar determinations and even inconsistency from the same informant when asked to repeat a naming exercise. Due attention should be given to techniques of triangulation in soliciting and verifying information related to local cultivars.

26. Heider (1970) thought that the issue of the large number of Dani names for sweet potato varieties raised tantalizing questions about the Dani language and horticulture. How much this project can further insights into the Dani language in relation to horticulture remains to be seen, but the relationship between names and cultivars should be closely documented.

27. Heider (1969) planned research for 1970 to map the Dani sweet potato lexicon more accurately by establishing the nature of micro-dialects or synonyms (i.e., different names for the same tuber): finding the real size of an individual's sweet potato vocabulary and the effects which variations in sex and age have on this vocabulary: and determining the physical criteria for naming vines, raw tubers, and cooked tubers. Was this ever done? The project may wish to contact come of the key researchers of the past, such as Heider, to follow up on any leads and request clarification.

28. Elsewhere, (Schneider 1995:65) has expressed doubts on Heider’s suggestion that the Dani use a sort of “playful naming” leading to inconsistency in the variety naming. Schneider (pers. comm.) also found that women’s information in specific locations (gardens) on their varieties was consistent. Project personnel will need to keep these conflicting reports in mind when dealing with cultivar identification by local people.

6.2.4.2. Gender and Age Considerations

29. Sillitoe (1983) found that women had a higher score in identifying cultivars than men. Women's everyday work puts them into closer relationship with this crop, so we can expect their knowledge to be more developed than that of men. So women know best about the characteristics of sweet potato cultivars (Schneider et al., 1993). It appears, therefore, that surveys, interviews and fieldwork on local cultivars should be carried out with the cooperation of local women.

30. However, Widyastuti (1995:40) found women to be responsive when interviewed in their own group, but silent when interviewed in mixed groups including men, concluding that interviews should be conducted separately to elicit adequate information from women. She states that both men and women should be interviewed to cross-check information, and further verified with information from old people and other key informants.

31. Plarre (1995) claims that his best informants were children of about 12 years of age, so obviously children should not be overlooked, and perhaps even sought out as informants concerning cultivar identification.

6.2.4.3. Documentation of Cultivar Information

32. According to Prain et al. (1995:706), the boundary between useful and superfluous information is subject to disciplinary biases of research team members and should be negotiated. They provide the example that biological scientists on their team were reluctant to collect information on rituals associated with crops and farming, despite the well-documented anthropological importance of such data. The project team members, through negotiated outcomes, will need to respect and honor the professional and pragmatic value of diverse types of information throughout the life of the project.

33. Takagi (1987:156) notes that since so many cultivars grown under such diverse conditions, proper records of collecting site and environment are important in carrying out subsequent evaluation research. This should be noted by the project and others in future collecting and documenting missions.

34. Prain et al. (1995:711) found that information on comparative agronomic performance of varieties was difficult to obtain. The found that local people were much more interested and willing to differentiate varieties according to consumption characteristics. Project personnel may wish to keep this in mind when they attempt to gather these types of data.

35. There is little knowledge about whether the varietal mixtures of sweet potatoes (10-40 varieties per bed) planted by the Dani are determined by consumption needs or by adaptation to micro-environments (Schneider, 1995:65). Some investigation of this topic with local informants at planting time may help shed some light on this dilemma.

6.2.4.4. Conservation of Local Cultivars

36. Matanubun et al. (1993:60) note that genetic diversity (i.e., the existence of certain varieties) of sweet potato may be under threat of disappearing in the future, as people tend to plant varieties that are known to have a high yield, as in the Kurima subdistrict of Jayawijaya district. It will be important to note as well, if this replacement process is indeed occurring, the sources of the replacement varieties, and whether local or introduced. Sowei (1993:87) shows that most international accessions at Laloki research station in PNG came from IITA in Nigeria (5), Japan (2), SPC in Fiji (9), and AVRDC in Taiwan (20).

37. The valuable genetic resources in sweet potatoes must be maintained, as there is a great need to utilize them in modern plant breeding. Plarre (1995) recommends *in situ* conservation in connection with on-farm projects organized in collaboration with Indonesian institutions. The project should bear these concerns in mind before it introduces improved varieties that might replace local varieties in a wholesale manner, and the recommendation for on-farm projects seems in keeping with current project design. However, Sowei (1993:81) notes that maintenance of field genebanks, at least in PNG, is a difficult task, and the training needs of germplasm curators must not be overlooked.

38. Takagi (1987:151) also notes that while the living collection performs the role of maintenance of cultivars, the collection of true seeds serves as an important alternative or supplement towards long-term conservation of the genetic diversity of sweet potato.

39. Schneider (1995b:2) noted that not only gene banks, but also living farming systems must be considered for genetic conservation strategies. This will become particularly cogent if, as mentioned in below, substantial replacement of indigenous systems by cash cropping is occurring.

6.2.4.5. Genetic Variability and Improvement

40. Bradbury et al. (1985) conclude that improvements may be made in protein quantity rather than quality by selection and breeding because of greater quantity variability and a minimal loss of essential amino acids due to amino acid imbalance. They found that PNG highland cultivars like Simbul Sowar and Takion, which combine high protein with only moderate variabilities across environments, are likely most useful for selection/breeding for high protein.

41. Plarre's (1995:10) coefficients of variation indicate large variability (Table 5). The frequency distribution follows a normal curve, common for quantitative features influenced by genetic and environmental factors, suggesting great chance for improvement in protein content by selection. Plarre (1995) thinks that both protein quantity and quality can be improved in sweet potatoes by precise screening, noting that the composition of essential amino acids is more favorable in highland cultivars than lowland ones, although the total amount of protein is reduced (Oomen et al., 1961). This should be good news for project breeders.

42. Tubun and Karafir (1990) conducted on-farm research on sweet potato selection, cultivation methods and productivity in Manokwari. Although the longest vines were still obtained from the local clone using the farmers' traditional practice, and there were no statistical differences between clones and planting methods for fresh shoot weight, tuber yields differed markedly, with the introduced clone outperforming the local one. The local clone grown by two methods produced 3.17 and 5.24 t/ha, while an introduced clone produced 14.30 and 17.71 t/ha under the two methods. They concluded that high yielding clones need to be introduced to replace the local one (but see caveats above). However, they note that the introduced clones have to be acceptable to local demand with regard to quality and taste.

43. Prain et al. (1995:711) found that farmers were interested in "months to harvest," or the length of time it takes before large roots can be harvested. Achamdy and Schneider (1995:74-5) likwise found that farmers in Jayawijaya tend to select shorter-maturing varieties, but thorough studies on the trends at macro- and micro-levels are lacking so far. Again, this consideration should merit consideration in gap analysis.

44. Earliness was also one of the characters sought by farmers with whom Schneider (1995:69) worked, and he feels that these farmers would readily accept varieties from formal plant research and breeding with such traits if they prove locally adapted. He therefore proposes a symbiotic relationship between formal agricultural research and local practitioners of crop development ("curatorship plus participation in variety evaluation") to ensure the continued use of local cultivar inventories and the evaluation of new material. Such participatory development, combining conservation and farmer-driven evaluation of traditional and improved crop varieties, would involve farmers at an early stage in variety evaluation and ask them to experiment with seed selections from breeding programs. This seems like very good advice to the project and a sound approach for conserving local varieties while helping farmers evaluate introduced ones.

6.2.5. Cultivation, Crops and Fertilization

45. Whether or not the development of silviculture practices is associated with the introduction of sweet potato into the highlands, as suggested by Golson (1977), will remain speculative until more direct evidence is found (Haberle et al., 1991:38). However, it is unlikely that the current project will be able to shed light on this paleontological question.

46. In a study by Levett (1993) in the dry lowlands of PNG, method of planting sweet potato (horizontal/vertical orientation and number of nodes) did not significantly affect total yield. However, the percentage of non-marketable tubers was affected. Levett also found that delaying the harvest from 108 to 133 days after planting resulted in greater damage to tubers and a higher percentage of non-marketable small tubers. He concluded that the potential for increasing sweet potato yields by modifying planting methods was limited and cultivar dependent. Furthermore, altering planting density is unlikely to improve marketable yield significantly. This lends some weight to the claim by Heider that it will be difficult to make improvements in the Dani sweet potato cultivation system.

6.2.5.1. Introduced Crops

47. There are now a variety of introduced crops in the highlands that are valuable cash crops (potatoes, carrots, cabbage, coffee), but the process whereby these crops start to change cropping patterns and garden types has not been documented for the Baliem valley. Schneider et al. (1993) however, conclude from studies in PNG (Waddell, 1972: Bourke, 1985a) that such a process is likely to occur in the future. It might be therefore useful and significant to begin to document the extent of such changes in cropping patterns and garden types.

48. Working around Manokwari, Dedaida (1986; cited in Karafir, 1987:321) compared the economics of upland rice with sweet potatoes in indigenous and transmigrant farms. He found that in one year, the per hectare return-cost ratio of upland rice and sweet potato was 3.3 and 7.5, respectively, showing sweet potato production more efficient than that of rice. Karafir (1987:321) thinks that this statement should be reconfirmed by doing economic analyses in other regions, particularly the Baliem valley and Paniai.

49. In light of severe food shortages in the aftermath of the ENSO-related drought of 1997/98 in Irian Jaya, Ballard (2000) predicts an increased role in the future for certain introduced crops such as the Irish potato, cabbage and carrots, at the expense of traditional staples. To what extent has this prediction come true?

50. Heider (1969) noted that both missionaries and the Indonesian government have introduced new crops, including new strains of sweet potato, into the Grand valley in order to improve Dani diet. However, he contended that it is widely recognized that it would be hard to improve the sweet potato cultivation system of the Dani, whose complex ditches are well suited to conditions of the valley. He also speculated that maybe sweet potato cultivar names are functional as well and should be understood before replacing traditional patterns. These concerns warrant bearing in mind, and respect for the fundamental genius of the Dani sweet potato cultivation system certainly seems to be a good starting point for the project.

51. Schneider (pers. comm.) thinks that one can be even more specific: It is hard to invent something better than the *wen-tinak* system for the cultivation of sweet potato under the conditions of the valley floor. But Schneider feels that this does not exclude crop introductions – intended to benefit Dani diet and produce a marketable surplus. It seems possible to Schneider to diversify cropping patterns on the basis of the *wen-tinak* system.

6.2.5.2. Fertilization

52. Bourke (1977:73,94) notes that because of the significance of sweet potato as a cash crop in PNG, information on fertilizer requirements is needed. Yet there is little, if any, information available on either its cash crop status in Irian Jaya or its response to fertilization. These are both areas where the project can add greatly to the state of knowledge regarding sweet potato production and consumption in Irian Jaya.

53. Bourke (1977:73) found that nitrogen consistently increased top growth of sweet potato on volcanic soils in PNG. However, he also warns that an excess of nitrogen should be avoided because this may cause excessive top growth, with a reduction in tuber yield. Indeed, this is a consideration for project personnel. However, this information should likewise be kept in mind if the project finds reason and opportunity to promote the use of sweet potato vines and leaves for enhancing pig production.

54. Furthermore, Bourke (1977:94) found that the economics of fertilizer use on the Gazelle Peninsula of PNG were favorable, with the cost of N fertilizer returned many times over. Overall, the use of phosphate fertilizer was not economic, whereas potash was economic only at moderate rates. However, it must be recalled that these economic considerations were based on the situation in PNG over 20 years ago. More importantly, they were based on the fact that sweet potato in PNG is a significant cash crop. The economics of fertilization in subsistence systems in Irian Jaya is not reported in the literature. Yet it is known that pork, as well as live pigs, constitute an important sector of commercial economic activity in Irian Jaya. Therefore, the economics of fertilization, with returns on investment accruing indirectly through provision of greater quantity, and/or higher quality feedstuffs for pigs should be considered by the project.

6.2.6. Consumption of Sweet Potato and Other Pants by Humans

55. Karl Heider (1979:34, cited in Aditjondro, 1982:66) worried about the future of the highlanders' sweet potato. "For most Indonesians, rice is the proper food and the sweet potato has very low status indeed. But since the Dani cannot grow rice, it would be both economically and nutritionally disastrous if they got drawn into a rice diet." To what extent have the Dani been drawn into a rice diet, and to what extent do they grow their own rice. This is an interesting question to bear in mind.

56. However, from Schneider's (pers. comm.) observations in Wamena, so far only few Dani have been drawn into a partial rice diet; mainly those working for the government, as he claims they get rice provisions as part of their salary. As local food stalls in the town normally do not serve sweet potato, Schneider also found it common to see Dani eating rice there. He does not share Heider's view that the Dani "cannot grow" rice. As any innovative farmer, they can – whether they should, as told by the Indonesian government is another question according to Schneider, who also notes that in the 1990s, a number of rice plots had emerged along the street to Jiwika. The balance between rice and sweet potato, the trade-offs involved between the two crops, and the comparative advantages of each deserve considerable project attention.

57. Plarre (1995) estimates that the protein yield of harvested crops he analyzed among the Mek accounted for the required daily supply. However, the question remains: is the protein quality sufficient for children, who are nursed up to two years old, and pregnant women? He recommends further investigations into this open question.

58. Schneider (pers. comm.) notes that pandanus was always mentioned to him as an important traditional source not only of fat, but also of protein, noting as well that there are scattered stands of pandanus trees in the vicinity of many Dani villages. This is a seasonal, not a permanent source of protein, but Schneider's impression is that it is an important supplement that should not be overlooked. Another such source, according to Schneider is a native (*Phaseolus tetragonolobus*) bean that is grown in many gardens.

59. Lawrence (1979:47) notes that if sweet potato formed a smaller proportion of the diet, with other crops contributing more, the incidence of pig-bel disease would be much less common. The implication is that project personnel might wish to not only investigate proper dietary balance of pig feed (see below), but also proper balance of the human diet as well.

6.2.7. Sweet Potato for Pig Feed

A number of studies, particularly in PNG, have looked at the suitability of sweet potato for pig feed. There are a number of suggestions, recommendations and caveats implicit, and explicit, resulting from this work. These are listed below.

60. Working in PNG, Malynicz and Nad (1973) conclude from comparison of their data with those of Vanscoubroek et al. (1967, cited in Malynicz and Nad, 1973) that the weight of pigs in feed trials may affect results and that there is a possibility that nutritional requirements and growth rates are different in tropical versus temperate environments. The implication is that in order to generate comparable data, attention should be paid to the starting weight of trials pigs, and caution should be used when comparing data from tropical environments like New Guinea with data from temperate regions. In their trials, Malynicz and Nad (1973:140) report mean initial pig weights varying between 15.1-16.1 kg (± 2.5-4.6 kg) and mean final weights between 50.8-59.2 kg (± 3.8-8.2 kg). Elsewhere, Rose (1981) reports on pig feed trials that commenced when pigs were three months old (7.2-7.8 kg mean initial weight).

61. Studies by Malynicz and Nad (1973) suggest that Zarate's (1956) findings that the digestibility of fibre in sweet potato vines was much higher in native Philippine pigs than either the Berkshire or the Berkjala (hybrid of Berkshire and indigenous Jajala) may apply to PNG village pigs versus exotic commercial breeds. The implication to be drawn here is that the results from trials with exotic pig breeds may not appertain to indigenous pigs. Therefore, trials should be conducted with indigenous breeds to assure applicability to the village situation.

62. Experiments in PNG reported on by Watt (1973) show that people who want to make money from pig raising should feed each pig 454 g of commercial concentrate per day and *ad lib* cooked sweet potato, as economic benefit from this investment far exceeds the cost. For people who just want bigger pigs than other people have, anywhere from 113.3 to 454 g of concentrate per pig per day is still recommended. The implication of these studies is that protein supplementation is desired when sweet potato constitutes the pig feed staple. However, if firewood has to be purchased to cook the sweet potato (454 g of firewood to cook 3,178 g of sweet potato), there is probably no economic gain in cooking the sweet potato (Watt, 1973). Rose and White (1980) conclude that further research is desired to determine if cooking of sweet potato for pig feed is worthwhile under local conditions (limited firewood resources and village pigs) in PNG, which also pertain to Irian Jaya.

63. As a result of research in PNG, the following recommendations are made by Watt (1973:141), which project personnel may wish to consider when planning pig feed trials and recommendations for farmers:

1. Soybeans and peanuts must be cooked before feeding to pigs.
2. Salt should be fed with soybeans.
3. Sweet potato is no a suitable food on its own.
4. Cooking sweet potatoes increases the daily live weight gain (by about 40%) and food consumption when compared with raw sweet potatoes.
5. Protein concentrate should be fed at the rate of 454 g per pig per day for maximum results.
6. The mixing of 454 g of concentrate with 4,540 g of cooked sweet potatoes gives slightly better results than feeding cooked sweet potatoes under the Lehmann system.
7. Grazing sweet potatoes is a satisfactory method of feeding.
8. Pigs grazing sweet potatoes require protein supplement of 454 g concentrate per pig per day.

64. Malynicz and Nad (1973) note that several authors have recorded decreased weight gain and intake and adversely affected food conversion ratio for pigs at high temperatures. Rations containing higher protein levels than are recommended for temperate areas may be required in tropical environments to compensate for lower energy intake by pigs at high temperatures (Devendra and Clyde-Parris cited in Malynicz and Nad, 1973). Malynicz and Nad (1973) also found that restricted feeding of commercial ration resulted in 30 percent less feed required per unit weight gain in exotic pigs. Therefore, they do not recommend unrestricted grain feeding. Again, project personnel may wish to consider the implications of these results, and whether or not they pertain to "village pigs."

6.3. Pig Husbandry and Use

65. There is considerable scope for improvement and development of pig management systems, the main requirements of which are delineated by Walters for PNG, with some application to Irian Jaya (1981:275):

1. Understanding of the socio-economic role of the pig in villages and of changes taking place in this role.
2. Understanding of the human-food-pig relationships.
3. Improvement of productivity by:
   a) Increasing genetic potential by use of European breeds, crossbreeding and removal of lower potential animals including feral boars,
   b) Reducing mortality and unthriftiness through vaccination and antibiotics. Cargill (pers. comm.) notes however that although the use of vaccinations may be practical, a word of caution is in order, both because supply would be difficult and because the likelihood of withholding periods not being understood or followed. Before prescribing or using antibiotics, veterinarians should ensure that the withholding period is adhered to, to avoid a build up of antibiotic resistance in human populations.
   c) Improving management methods.
4. Improvement in pig food availability by: a) Intensification of root crop production, b) Increased development and availability of other food sources, and c) Development of storage systems to ensure continuity of supply.
5. Adoption of means of storing and preserving pig meat.

6.3.1. Description and Modification of Existing Systems

In addition to the above considerations, there are a number of other issues related to pig husbandry that the project may wish to consider:

66. It might be interesting to follow pigs that are free-ranging, by doing pig anthropology, and discover exactly what, and how much/how often, they are eating. This might debunk the notion that sweet potato roots and vines constitute 100% of pig diet, especially in light of observations by Rose (1981) that rooted earthworms may constitute an important source of protein for village pigs.

67. Heider (1970:50) notes that a few compounds among the Dani have special pig runs, which are fenced areas in the banana yard where pigs can run and root. However, he notes that these are quickly rooted out by the pigs and in fact are seldom used. Nonetheless, if the "pig run" was combined with a rotational system, like that described by Watt (1973) there could be some potential. Watt took an area of one acre, subdivided into ten equal paddocks, planted to sweet potato at one-month intervals. The pigs were allowed to stay on one of these paddocks until it was grazed out, then they were moved to the next one, and the original one was then replanted immediately. The results in live weight gain were very satisfying and the managerial skills and effort was lower than intensive husbandry. Moreover, there was no appreciable drop in yield of sweet potato over a period of three crops (Watt, 1973). This latter, perhaps, because of the direct addition of pig manure to paddocks? It is a modification of the free-ranging system, involving sweet potatoes, that perhaps merits investigation in the current project. Cargill (pers. comm.) notes that this method was adapted in Tonga with great results.

6.3.2. Commercial Intensification of Pig Husbandry

68. Walters (1981) reports that by 1981, PNG had an apparently economically viable peri-urban fattening piggery system, based on exotic weaners (Large White-Landrace crosses) and feedstuffs (grower ration with 16% crude protein). Growth rates of well above 500 g/day had been obtained, and batches were ready for slaughter after only 70 days. Compound feedstuffs ensured a nutritionally balanced diet, and reduced labor time in production of staple foods. Prospects looked good in 1981, because supply was clearly below demand (Walters, 1981:277). In light of the intervening 20 years, it might be important to obtain a recent assessment of this intensive system in PNG, and begin to draw some lessons from the experience for similar intensification efforts in Irian Jaya.

69. Aditjondro (1982:65) claims that both the Dutch and the Indonesian administrations were unsuccessful in developing interest in commercial pig farming among the hill tribes, whose interest in pigs was mostly ceremonial. Undoubtedly, the project will want to investigate the extent to which commercial pig farming has developed in Irian Jaya, if at all.

70. Schneider (pers. comm.) adds that interest in commercial pig farming has been low exactly for the reason given by Aditjondro. He feels that there is willingness to sell pigs among farmers, as witnessed by the small pig market in Wamena, where men from the villages offer pigs for sale. However, Schneider claims that it still seems to be a hard thing for them to sell pigs, as their exchange value in the traditional system is very high. Commercial production of pigs specifically for the market has not developed. Again, this issue deserves considerable project attention.

6.3.3. Pigs and Pork in Diets and Markets

71. Lawrence (1979:47) warns that possible dietary change by killing and eating pigs more frequently may actually be dangerous. He claims that more frequent eating of meat, if not enough to result in improved protein nutrition, and coupled with persistence of sweet potato as the staple, may lead to more pig-bel disease. He concludes that advice on changing dietary habits to eliminate pig-bel should be given with caution.

72. There appears to be virtually no information available in the literature regarding the commercial marketing of pork in highland communities of Irian Jaya. It will be important for the project to begin to diagram marketing chains from production to consumption. Another implication can be drawn from the literature in relation to the role of pigs and pork in both subsistence diets and commercial markets. Heider (1970:58) said that fish, not native to the Grand valley, were introduced by the government since 1960, and Dani were encouraged to dig special fishponds. Heider predicted that in the future fish would probably become an important source of protein for the Dani but has it, and to what degree has it replaced pork?

73. Schneider (pers. comm.) notes that in the Baliem valley, fish (carp) is indeed produced in ponds following the imported western Indonesian techniques, but was at the time he was there not an important source of protein, nor was there an abundant supply of it on the Wamena market. Still, the issue warrants further investigation by project personnel.

6.4. Integrated Humans-Sweet Potatoes-Pigs Systems

A number of studies have alluded to the linkages between local inhabitants, their sweet potatoes and agriculture more generally, and their animal husbandry, specifically pigs. Some of these relate to climatic and edaphic limitations to production, others to the notion of carrying capacity, and yet others to the traditional survival strategies employed by inhabitants. To the extent possible, project personnel may wish to address these concerns.

6.4.1. Climatic and Edaphic Limitations

74. Brookfield (1964:25) posited a need to examine closely the available information on climate and weather in order to better understand the limiting conditions to sweet potato cultivation and their location, and the reason why small differences in weather can have marked ecological effects. It will be important, in this regard, for the project to monitor closely climatic data from weather stations in relation to any project trials or other experiments, so that relationships can be drawn or hypothesized.

75. Goodbody and Humphreys (1986) underscore the need for a knowledge of native soil factors influencing potential yield in areas of subsistence agriculture where artificial fertilizer is expensive and rarely available. In their studies in PNG, they found that available phosphorus is related significantly to sweet potato yields, even though sweet potato is generally considered to have a low requirement for P. They also found that were phosphate retention is a significant component of regression, its effective is positive, with higher yields related to higher phosphate retention. They also found a positive correlation between pH and yield, although elevation of pH above 6 is not associated with increased yield. Ignatieff (1958, cited in Goodbody and Humphries, 1986) gave a preferred pH range for sweet potato as 5.8-6.0. Interestingly, Karafir (1987:321) claims that tuber crops like sweet potato are known to degrade land fertility quicker than grain crops such as rice. What does the project know about this?

6.4.2. Carrying Capacity

76. Heider (1970:60) thought that the determination of carrying capacity among the Dani was problematic. He hypothesized that if basic sweet potato and pig production was maintained while population increased, eventually there would be too many people for the land. A good measure of this would be whether the Dani food supply was adequate in terms of minimal standards of protein, calories and such. But these standards, relevant to the Dani, would have to be established by a comprehensive study that also measured the food values of the present Dani diet, and determined the maximum potential food production on the land by present Dani methods. Whether this is something beyond the scope of the present project is certainly a valid question, but it is nonetheless an important area of consideration since the project aims for poverty alleviation and food security.

77. Based on the calculations by Karafir (1987:318-9), it would appear that Heider's prediction above was accurate. For Jayawijaya Regency in 1985, Karafir estimated sweet potato production at 230,124 t, and human sweet potato consumption need at 359,137 t, indicating a sweet potato shortage of 129,013 t.

If there is any reliability at all in Karafir's estimates, the food shortage problem in Jayawijaya would be substantially more critical than indicated, since Karafir does not seem to take into account the consumption of sweet potatoes by pigs! However, given the great difficulty of collecting data that would cover the regency, Schneider (pers. comm.) suggests treating these data with utmost caution. He thinks these are more an extrapolation than statistically reliable data. Nevertheless, the project should be aware that there might be a considerable food shortage in the highlands with respect to sweet potato, which would present the project with both a challenge and an opportunity.

78. Evidence suggests that highland land management systems are resilient and have changed little during a period of major social and economic upheaval (Brookfield, 1991:209). Brookfield also notes that these production systems are less disturbed by depletion of male labor for other economic activities, since they rely heavily on female labor. Cash-cropping and off-farm employment have reduced vulnerability to food shortages in some areas (Bourke, 1988: cited in Brookfield, 1991:209), but with a population growth rate over two percent a year, Brookfield feels that the system may be threatened by socio-economic as well as environmental change. He calls for comparative analysis and discussion of findings on, among others, the experience of change in economic and social conditions. The project has an important opportunity to contribute to this discussion.

6.4.3. Survival Strategies

79. Ballard (2000) thinks that an investigation of traditional strategies during times of crisis (e.g., drought and food shortages) is necessary. This is probably a good suggestion in light of earlier claims by Gardner and Heider (1968:44) that no Dani ever starves, except for those who have gardens that are periodically flooded on the banks of the Baliem River. In Anggi, Karafir (1987:318) claims that sweet potato shortages appear seasonally, especially after planting. Apparently, the local people have tried to overcome this by first planting corn and pumpkin that can be harvested during the nursing stage of sweet potato (Karafir et al., 1984: cited in Karafir, 1987:318). He does not know, however, whether or not such a strategy has been adopted in Baliem and Paniai as well. Group interviews concerning survival strategies employed during the 1997/8 ENSO drought-related food shortage, and other seasonal shortages, might shed light on this issue.

80. Stating that subsistence is possible is different from saying that nutrition is adequate, a mistake made by some agriculturalists (Oomen, 1961). However, precise information on all the factors concerned should precede improvement of the menu by outsiders. How much harm is caused by dietary deficiencies? How is harm localized and what groups are specifically or particularly at risk? Which situations are urgent enough to require corrective action? Again, on-site investigation into the aftermath of the 1997/8 ENSO-related food shortages may begin to reveal partial answers to these questions.

6.4.4. Storage

81. Brookfield (1964:24, 33) noted that a reported short drought in 1957 in the Baliem valley led to widespread alarm, even though Wamena records show no month with less than 2.5 inches (63.3 mm) rainfall. The fact that such a weak drought generated serious alarm reveals, according to Brookfield, the precarious nature of agriculture when there is no food storage. Highland agriculture, without food storage, is particularly sensitive to drought, and therefore only the moister valley flats in the Baliem valley are densely occupied, with techniques that allow water to be retained, as well as drained.

82. Moreover, Schneider (pers. comm.) notes that the current system (staggered planting, harvesting) is geared towards "storage of tubers in the soil," thus making the system susceptible to weather and climatic micro-changes. Brookfield's concerns, and Schneider's comments, suggest that some investigation of locally appropriate storage strategies (sweet potatoes and pork) may well be warranted.

6.4.5. System Modifications

83. Oomen (1961:63) thinks that green manure would improve the soil and shorten fallow periods, and obviate the need for imported fertilizers. Cultivation of legumes might also bridge the protein gap (and provide some fat), as might extension of animal husbandry and fish-raising. However, Oomen thinks it simpler to convince the highlander of the advantages of "valuable, protein-rich, productive varieties" of sweet potato than any other measure. While better and best strains exist among varieties in use, real improvement may have to come from outside varieties (Oomen's caveat: import of a dangerous virus, like the disease of the Irish potato, could do more harm than good). Probably investigation of cover cropping and use of green manure is warranted as another potential research direction, important for sustainable agriculture. This is also suggested by work done in PNG, where a peanut (*Arachis hypogaea*) or winged bean (*Psophocarpus tetragonolobus*) rotation is commonly employed to maintain soil fertility in sweet potato cultivation systems (Bourke, 1985a).

84. Soenarto and Rumawas (1997:66) concluded that the main factor affecting the improvement of crop environments in the Dani *wen-tinak* system of wetland cultivation was the canal, which acted as a nutrient trap in which nutrient enhancement processes occurred. The only removal of vine material from the raised bed mounds was between months five to eight after planting, for both new planting material and for consuming as a vegetable. After month eight, the vine material was tossed into the nutrient trap. If vines are to be used as pig feed to any degree, this nutrient aspect of the crop residue must be taken into account, because the mud from the ditches in the *wen-tinak* system is a valuable source of nutrients, especially N, for the subsequent sweet potato crop.

85. Preston (1990) noted that farmers in Enga Province, PNG, believe that the use of compost helps to prevent tubers from rotting. In fact, Preston found less black rot, caused by *Ceratocystis fimbriata*, on tubers from mounds with compost (2.5%) than on mounds without compost (13.4%). Any system modification that reduces the native use of compost should keep this finding in mind. Preston (1990) also found that positive and negative compost x fertilizer interactions do occur, and can be of the same order of magnitude as the main effects. Floyd et al. (1988:23) likewise obtained experimental results that suggest that the combined use of compost and fertilizers, particularly phosphatic, requires further study. Therefore, it is important to bear this in mind if the project promotes the use of inorganic fertilizers along with native composting.

86. It has been noted that Floyd et al. (1988) found that the response of sweet potato yields to organic composting was linear over the measured range. They conclude that this indicates considerable scope for increasing sweet potato yield by increasing the rate of composting. However, they also note that substantial increases in composting rates will require collection of organic material outside the garden, thus increasing labor requirements of women responsible for sweet potato cultivation. The burden of work on women, already excessive in many areas of the highlands (Allen et al., 1980; cited in Floyd et al., 1988:17), would likely restrict the practicality of increasing composting rates in subsistence systems. Moreover, the lack of residual effects from composting would mean that the additional labor of collecting more material would not be spread over a number of crops (Floyd et al., 1988:17). Project personnel will need to be mindful of the labor requirements, particularly on women, of any proposed intervention.

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9. Tables

Table 1. Climatic data of some locations in Irian Jaya.

	Wamena[1]	**Kosarek[2]**	**Eipomek[3]**	**Eipomek[4]**	**Rendani-Manokwari[5]**
Elevation (m)	1550	1500	1800-2000	1600-2300	130
Annual rainfall (mm)	1800	>5000	5900	6000	118.2-431.3 (monthly)
Dry months (n)	-	-	-	-	-
Average max temperature (°C)	25	31.0	24.0	+25	27.40
Average min temperature (°C)	15	15.0	12.0	11	26.82
Average relative humidity (%)	78	n/a	n/a	n/a	82.42-85.00

[1] Period 1973-1984, cited in Soenarto (1987;6).
[2] Calculation from two months (Plarre, 1995).
[3] One-year measurement by G. Hoffman, cited in Plarre (1995).
[4] Schiefenhövel (1982).
[5] Data from 1977-1986 cited inTubun and Karafir (1990).

Table 2. Nutrient cycles in the Dani *wen-tinak* sweet potato cultivation system (adapted from Soenarto.and Rumawas, 1997;64-5).

Subsystem/Output	Weight (kg)	Amount of Nutrients (g/m2)
Raised bed		N=760.00 P[1]=104.00 K[2]=64.00
Mound	101.1	N=640.00 P=149.31 K=65.00
Mud layer in ditch		N=1060.00 P=173.06 K=82.66
Mud layer on bed	31/mound	N=146.17 P=23.86 K=11.40
Grass	3.8/m^2	N=32.49 P=0.66 K=3.99
Sweet potato plant[3]	2.4/m^2 fresh wt. vines 4.3/m^2 fresh wt. roots 0.469/m^2 dry wt. vines 1.336/m^2 dry wt. roots	N=6.48 P=0.34 K=1.00
Crop residues	2.4/m^2	N=3.37 P=0.10 K=0.49
Harvested tubers	4.3/m^2 fresh wt. (31% dry matter)	N=2.91 P=0.24 K=0.51
Sweet potato cuttings[4]	0.115/m^2 fresh wt. 0.040/m^2 cuttings 0.075/m^2 vegetables	N=0.104 P=0.003 K=0.014

[1] P2O5
[2] K2O
[3] Eight months after planting
[4] During the period five to eight months after planting.

Table 3. Number of sweet potato cultivars grown by various groups in Irian Jaya.

Location	Cultivars	Source
Jayawijaya subdistrict	± 600	Achmady and Schneider, 1995;72)
Jayapura subdistrict	15	Achmady and Schneider, 1993 cited in Achmady and Schneider, 1995;72)
Wamena market area	81-200	Wiriadinata (1995;89)
Baliem Valley (1650 m)	70+	Heider (1970)
Kuyawage	30	Schneider et al. (1993;40)
Malagi	28	Schneider et al. (1993;40)
Baliem Valley	15-43 (average of 30)	Schneider et al. (1993;40)
Jiwika	57	Aditjondro (1987;109)
Jiwika	28	Tjondronegoro (1971;35)
Kosarek (1500 m)	45 (11)*	Plarre (1995;7)
Eipomek (1800 m)	50 (12)	Plarre (1995;7)
A Grand Valley Dani group	48	Peters, 1965 cited in Heider (1969;78)
Wissellakes region	55+	Oomen et al. (1961;57)
Paniai	33	Suhar and Sawor, 1988 cited in Achmady and Schneider, 1995;72)
Paniai	55+	Tubun and Karafir (1990)
Anggi	60	Sawor et al., 1993 cited in Achmady and Schneider, 1995;72)
Kanaan Biak	88	Lasse, 1983 cited in Achmady and Schneider, 1995;72)
Arfak	15+	Tubun and Karafir (1990)
Unspecified	30	Hiepko and Schiefenhövel, 1987 cited in Plarre (1995)
Unspecified	34	Hiepko and Schiefenhövel, 1987 cited in Plarre (1995)
Unspecified	44	Hiepko and Schiefenhövel, 1987 cited in Plarre (1995)
Unspecified	81	LaAchmady (1988;103)

* Recently introduced.

Table 4. Sweet potato varieties grown as pig forage in the Baliem Valley, Irian Jaya (Widyastuti, 1995;38-9).

Musan
Tabogolek
Hulok
Saporengken
Lokobasok
Hitilom
Huwakeh
Nikiyawut
Koboak
Mingka
Tinta kuning
Tinta putih
Towenggon
Tabimbi
Apeh
Liduge

Table 5. Variation and frequency distribution in protein content in highland clones of sweet potato tubers from Irian Jaya (Plarre, 1995) and PNG (Goodbody, 1984).

Protein content (Nx6.25) in g/100 g dry matter	**Irian Jaya sweet potato clones (#)**	**PNG sweet potato clones (#)**
≤ 1.6	2	1
1.7-2.3	5	17
2.4-3.0	15	24
3.1-3.5	5	29
3.8-4.4	3	17
≥ 4.4	0	5
n	30	93
Mean	2.65	3.14
S (standard deviation)	± 0.7	± 0.4
S% (coefficient of variation)	26.4	N/A
Range	N/A	1.6-5.3

Table 6. Crude protein and starch and sugars in different sweet potato varieties from Irian Jaya (in percentage dry matter).

Variety	Crude protein*	Starch & sugars	Location & source
Kadakaga (red)	2.2	77.4	Wissellakes region, +1700 m (Oomen et al., 1961;58)
Kadakaga (white)	2.6	80.0	Wissellakes region, +1700 m (Oomen et al., 1961;58)
Egeida	3.4	79.3	Wissellakes region, +1700 m (Oomen et al., 1961;58)
Budodugi	2.9	79.5	Wissellakes region, +1700 m (Oomen et al., 1961;58)
Mogoudugu	2.6	81.0	Wissellakes region, +1700 m (Oomen et al., 1961;58)
Butikatoka	3.8	76.0	Wissellakes region, +1700 m (Oomen et al., 1961;58)
Genjem-1	4.8	78.5	Nimboran, +70 m (Oomen et al., 1961;58)
Genjem-2	9.2	73.0	Nimboran, +70 m (Oomen et al., 1961;58)
Various PNG accesssions	1.14-3.46	12.5-29.4 (sugars only)	AVRDC (1984; cited in Takagi, 1987)

* Crude protein, Nx6.25

Table 7. Average daily live weight gain of pigs under various conditions and diets in Papua New Guinea.

Diet and Conditions	Average Daily Live Weight Gain (g)	Location and Source
1. Pigs foraged on completely harvested raw sweet potato tubers from mounds after all other surface vegetation was removed, plus 20 g of concentrate (52% crude protein)	205 (*Sus scrofa papuensis*)	Piwa Agricultural Station (1,620 m), near Tari, Southern Highlands Province, Papua New Guinea (Rose, 1981)
2. Pigs foraged on sweet potato mounds where raw tubers were lifted from the soil but left attached to the vines and within reach of the pigs, plus 20 g of concentrate (52% crude protein)	191 (*Sus scrofa papuensis*)	Piwa Agricultural Station (1,620 m), near Tari, Southern Highlands Province, PNG (Rose, 1981)
3. Pigs were left to forage on grassland with no access to sweet potato, plus 20 g of concentrate (52% crude protein)	140 (*Sus scrofa papuensis*)	Piwa Agricultural Station (1,620 m), near Tari, Southern Highlands Province, PNG (Rose, 1981)
4. Pigs were under village conditions with variable localities and availability of feeds.	52 to 80 g (*Sus scrofa papuensis*)	Goroka, Simbu and Hagen areas of PNG (Malynicz, 1976); Simbu (Hide, unpublished data); Tari area (Rose, unpublished data) all cited in Rose (1981)
5. Pigs were penned on concrete and fed a balanced, grain-based diet	225 g (*Sus scrofa papuensis*)	Malynicz (unpublished data) cited in Rose (1981)
6. Pigs were housed on either concrete or deep litter floors and hand fed raw peanuts at daily rate up to 681 g with raw sweet potatoes fed *ad lib* (as much as the pigs wanted)	90.8 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
7. Pigs were housed on either concrete or deep litter floors and hand fed raw soybeans at daily rate up to 544.8 g with raw sweet potatoes fed *ad lib*	59 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)

Diet and Conditions	Average Daily Live Weight Gain (g)	Location and Source
8. Pigs were housed on either concrete or deep litter floors and hand fed cooked soybeans at daily rate up to 544.8 g with raw sweet potatoes fed *ad lib*	199.8 to286 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
9. Pigs were housed on either concrete or deep litter floors and hand fed soybeans with sweet potatoes plus common salt (with or without bone ash)	422.2 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
10. Pigs were housed on either concrete or deep litter floors and hand fed raw sweet potatoes *ad lib* plus a daily ration of 454 g of commercial concentrate (45-55% protein)	326.9 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
11. Pigs fed a normal station ration of sorghum and concentrate	567.5 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
12. Pigs were housed on either concrete or deep litter floors and hand fed boiled sweet potatoes *ad lib* plus a daily ration of 454 g of commercial concentrate (45-55% protein)	590.2 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
13. Pigs were housed on either concrete or deep litter floors and hand fed raw sweet potatoes *ad lib* plus a daily ration of 227 g of commercial concentrate (45-55% protein)	435.8 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
14. Pigs were housed on either concrete or deep litter floors and hand fed raw sweet potatoes *ad lib* plus a daily ration of 113.3 g of commercial concentrate (45-55% protein)	317.8 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)

Diet and Conditions	Average Daily Live Weight Gain (g)	Location and Source
15. Pigs grazed on sweet potatoes and were fed a supplemental salt mineral block	Lost weight	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
16. Pigs grazed on sweet potatoes and were fed a supplement of 227 g of margarine per day	Lost weight	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
17. Pigs grazed on sweet potatoes and were fed no additional food or supplement	No increase or lost weight	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
18. Pigs grazed on sweet potatoes and were fed a supplement of 544.8 g of meatmeal (50% protein) per day	345 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
19. Pigs grazed on sweet potatoes plus 308 g of protein concentrate (55% protein) per day	258.8 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
20. Pigs grazed on sweet potatoes plus 408 g of protein concentrate (55% protein) per day	372.3 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
21. Pigs grazed on sweet potatoes plus 208.8 g of whole peanut kernels per day	136.2 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
22. Pigs grazed on sweet potatoes plus 454 g of protein concentrate (55% protein) per day	408.6 g	Tropical Pig Breeding Centre, Goroka (Watt, 1973)
23. Three consecutive groups of pigs grazed rotationally on sweet potatoes plus 454 g of protein concentrate (55% protein) per day	544.8 g 635.6 g 499.4 g	Banz, PNG (Watt, 1973)
24. Pigs were housed on concrete and fed unrestricted grower ration (18% crude protein) based on sorghum and a commercial protein, vitamin-mineral supplement	507 $\pm$ 30 (Exotic commercial breeds)	Tropical Pig Breeding Centre, Goroka (Malynicz and Nad, 1973)

Diet and Conditions	Average Daily Live Weight Gain (g)	Location and Source
25. Pigs were housed on concrete and fed grower ration (18% crude protein) based on sorghum and a commercial protein, vitamin-mineral supplement restricted to 1.82 kg per day	447 ± 30 (Exotic commercial breeds)	Tropical Pig Breeding Centre, Goroka (Malynicz and Nad, 1973
26. Pigs were housed on concrete and fed grower ration (18% crude protein) based on sorghum and a commercial protein, vitamin-mineral supplement restricted to 1.82 kg per day; when pigs had completed their daily ration there were allowed free access to sweet potato foliage	410 ± 54 (Exotic commercial breeds)	Tropical Pig Breeding Centre, Goroka (Malynicz and Nad, 1973

9. Figure

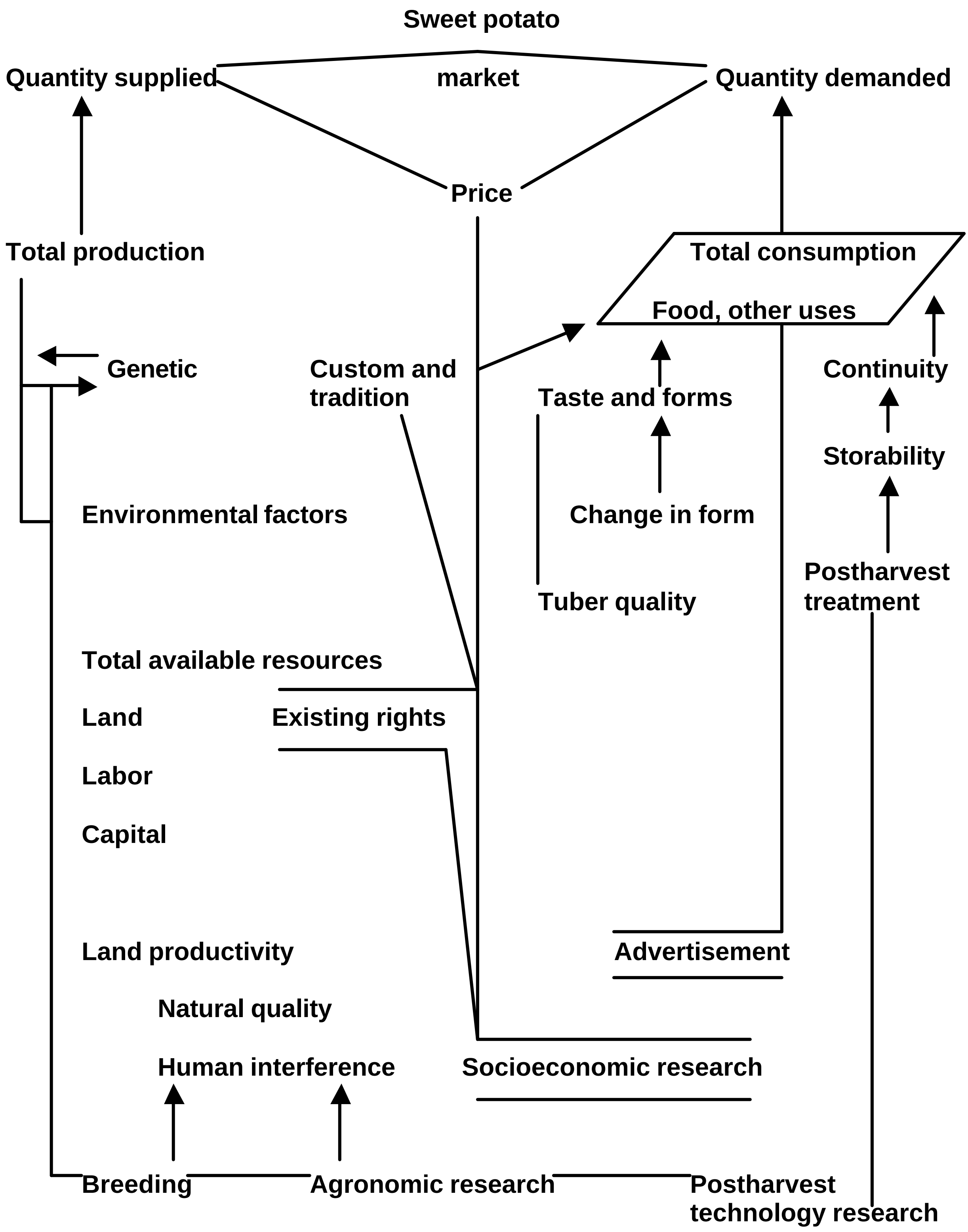

Figure 1. System approach to determine research programs for sweet potato development in Irian Jaya (Source: Karafir, 1987).