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How the Enga Cope with Frost: Responses to Climatic Perturbations in the Central Highlands of New Guinea

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The adaptive strategy of a population of New Guinea highland subsistence farmers is considered in the light of events surrounding a series of severe frosts experienced in 1972. Coping with frost is seen to be a critical preoccupation for all Enga, and agricultural mounding a universal response, adequate to deal with the mild frosts of Central Enga country below 2250 m but insufficient above. There, among the Fringe Enga, a sequence of responses at three different levels may be identified. These may be called the local, intraregional, and extraregional levels because of their progressively wider geographical spread in agricultural activity and attendant increased population mobility. A correspondence is indicated between response level and frost intensity. This response, while effective, is being modified through cropping innovations and disrupted by a colonial situation. Further, at higher levels, it is incompatible with the prescribed course of political and economic development.

KEY WORDS: frosts; migrations; New Guinea; natural hazards; sedentarization.

INTRODUCTION

During 1972, the Central Highlands of Papua New Guinea experienced a prolonged drought that, through a combination of high altitude and stable weather conditions, generated a long series of frosts that did substantial damage to both the food gardens of the local population and the natural vegetation. In the worst-hit areas, above about 2300 m, in excess of 30 nights of ground frost

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were experienced between June and October, while individual frosts were recorded as low as 1650 m, all this in a region where the subsistence food complex is almost exclusively of tropical lowland origin and therefore not frost tolerant.

Official response to this crisis was to declare a national emergency and mount a Famine Relief Program under the control of the Director of Civil Defense which had as its principal functions, first, to "maintain the existing nutritional status" of the estimated 130,000–150,000 people directly affected and, second, to make available a variety of planting materials to facilitate their rapid return to a state of self-sufficiency. The program ran for about 8 months, cost an estimated 3 million dollars (Australian), and involved a very substantial commitment of human and material resources on the part of several government departments and Christian missions. It proved eminently successful in that no evident hardship or loss of life occurred as a direct result of the frosts and no cases of corruption or discriminating practices in the distribution of relief supplies were reported.

While the relief exercise could not be faulted, the assumptions that underlay it were of questionable validity. A fundamental premise was that the victims had no satisfactory means of their own to cope with the crisis. Hence if no action were taken to provide them with relief, "forced migration" of people out of the affected areas would result, and this would in turn generate a whole series of "secondary effects" of the crisis, identified specifically as "social disorganization, a disruption of sanitation, and the spread of infectious diseases" (Ewald, 1972: 1). In this respect, officials concerned with the relief effort sought simply to follow guidelines established by the World Health Organization on the basis of famine relief experience elsewhere in actively discouraging movement and initiating a program of "replacement feeding" (Malcolm, 1972: 9) in disaster areas. Further reassurance for the legitimacy of the approach was provided by the widespread conviction that this particular climatic crisis was entirely without precedent.

A few officials were, admittedly, vaguely cognizant that a similar crisis had occurred some 30 years previously (just prior to sustained European contact in this part of New Guinea), but they were convinced that these earlier frosts were milder and had nevertheless resulted in widespread violence, starvation, and death. Massive out-migration was known to have occurred on this occasion but no one considered it to have been a *structured* response to the situation. Rather, it was interpreted as a disorganized fleeing of starving victims from the disaster area. The impression gained was of a severely malnourished population that disputed for the few remaining foodstuffs over a period of several weeks, and then, as a last resort, fled across the mountains in search of refuge at lower altitudes. The further impression was that their poor physical condition resulted in the death of many people en route, while others suffered from the hostile reception encountered at the end of their journey.

Even as a partial solution to the problem, such migration was discounted in 1972 on the grounds that declining agricultural productivity and population increase since contact rendered it impossible for the customary host areas to accommodate any additional population even for a short period. This long-term trend was further aggravated by the fact that this time these other areas were also experiencing the effects of the drought and even in some cases frost.

These expatriate-held convictions were not based on any formal evaluation of the 1972 frosts or investigation of previous experiences. Rather, they arose out of casual conversations with individual victims, plus overt pressures placed by these latter on expatriate organizations. Thus, on the one hand, stories dramatizing the previous crisis were eagerly proferred by a people well known for their penchant for overstatement – "Some died in their houses. Some died on the way. Only the bones were left." On the other hand, the local population was acutely conscious of the presence of government and mission authorities and the fact that they could be pressured into intervening on their behalf. So, for instance, members of the Wabag Lutheran Church knew the Lutheran mission to be actively involved in relief work in other countries. Why not here, too, then?[2]

A critical review of the Famine Relief Program has been undertaken elsewhere and conclusions have been drawn as to its inappropriateness (Waddell, 1972). The aim of this article is to complement the former in demonstrating that the local population has a whole series of mechanisms available to respond to the kind of climatic hazard experienced in 1972 and that the response is structured, its magnitude varying with the intensity of the climatic perturbation. This concern is in conformity both with a current preoccupation in human ecology – to investigate how people adapt to departures from steady-state conditions – and with natural hazard research, where there has been a shift in interest from perception to response. At the same time, this article seeks to challenge some of the assumptions underlying relief work – of crisis, unusual events, inadequate perception, and incoherent response – and provide the information necessary to assure more appropriate aid in the event of future frosts in the region.

[2] It is interesting to note in this context the sequence of events following the major, terminal frosts, as recounted by E. Bloos, lay missionary at Laiagam: "and then they started coming onto the station and saying, 'Everything is buggered up finish. Look at the ice.' They brought in sheets of ice. 'All our gardens are finished. What are we going to do for food?' And so here on our station several hundred people, most of the local head people got together and said, 'What are we going to do? We want you to go and talk to the Kiap who is the government administrator, and tell him about this.' So I did a patrol around the area on the main roads, on the motor bike; and this was pretty widespread, so we went down to the main government station and got them all out, the Agriculturalists, the Administrators and we agreed that it was a serious thing, so we notified Hagen" (ABC broadcast "Look Back at Famine," June 14, 1973).

THE ENGA, FROST, AND AGRICULTURAL MOUNDING

For most Enga – the people principally involved in the 1972 crisis – frost is a fact of life. Indeed, it provides the key to understanding the most distinctive element of their adaptive strategy, agricultural mounding.

The Enga number about 150,000 and are located to the west of the Mount Hagen range in the Western Highlands District (Fig. 1). They are concentrated principally in the Lagaip and Lai valleys in the vicinity of Wapenamanda, Wabag, and Laiagam government stations, but are also more widely distributed through the surrounding valleys and uplands over an altitudinal range of about 1600 m, from 1100 to 2700 m MSL. Their "mean level of settlement" is unusually high for major New Guinea Highlands populations, being 1900 m compared with about 1700 m among the Chimbu.

As is widely recognized, the Enga cultivate their staple food, the sweet potato (*Ipomoea batatas*), and at higher altitudes most domestic crops, in large mulch mounds that average in the Middle Lai valley about 3.18 m in diameter and 0.6 m in height (Fig. 2).[3] These mounds are designed to protect highly vulnerable crops from the particular type of frosts that are experienced in the Central Highlands, namely, radiation frosts. These occur on clear, still nights when outgoing radiation is excessive, and they are characterized by a marked inversion in the temperature regime close to the ground surface. Not surprisingly, they are restricted to the dry season in the highlands, and the inversions are generally of a moderate order. Thus recordings made at about 2650 m in the Sirunki area indicate that when temperatures in a Stevenson screen fall to 5.5°C there is a slight risk of ground frost, while below 4.4°C the likelihood is very strong. Under such conditions, the mound serves to modify to a significant degree the microclimatic regime of cultivated areas by both elevating the sweet potato plants above the zone of lowest temperature and facilitating the drainage of dense, cold air downslope. Thus planting is concentrated in the upper part of the mound, while the whole mound surface and the "channels" between are clean-weeded. The experimental work carried out at Sirunki indicates that, under conditions of high frost risk, minimum temperature readings on cleared, unmounded ground are of the order of 2°C lower than those on the upper part of the mound. Mulching further contributes to protecting the food plants from frost damage in that the heat generated by its decomposition raises soil temperature by about 1.2°C.

[3] The following discussion of the functional significance of sweet potato mounding represents a summary of the material presented in Waddell (1972) in the section dealing with "land use techniques in response to environmental constraints" (pp. 138-168). The same source contains a detailed discussion of the Enga agricultural system as well as a comparative analysis of the agricultural practices of other highlands populations.

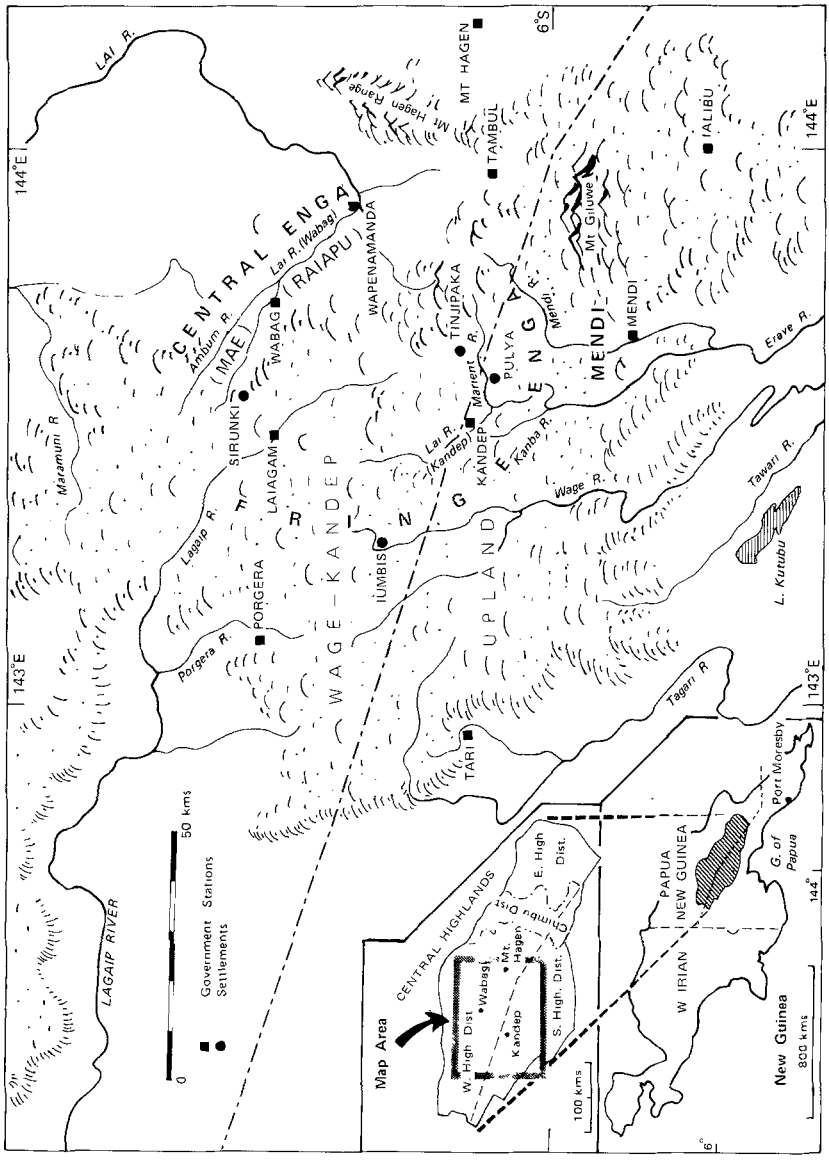

Fig. 1. Enga territory.

Fig. 2. Sweet potatoes are planted in large mulched mounds with, at high altitudes, the vines arranged concentrically around the top.

One striking confirmation of the functional significance of mounding is that the distribution of this practice through the highlands coincides closely with the distribution of the frost hazard. The Enga only mound above about 1520 m. Below that altitude they practice casual mixed gardening where the staple is intercultivated with the subsidiary crops. More generally, as Brookfield (1962: 250) notes, mounding is restricted within the highlands to an area centering on the Wage-Kandep upland and forming an extensive area of unbroken country and broad valley flats at altitudes in excess of 1825 m. Here topography, elevation, and a relative absence of cloud cover together actively encourage the concentration of cold air on agricultural land.

A phenomenon which is perhaps even more remarkable in the case of the Enga is the fact that certain attributes of the mound vary in relation to the in-

tensity and frequency of the frost hazard. Generally speaking, the gravity of the hazard increases with altitude. Mound dimensions, minimum height above the ground at which the sweet potato vines are planted, and the degree of tillage of the soil similarly vary largely with altitude. A survey and classification according to similarity analysis of a large number of mounds through the Lai valley indicated the following. There is a general increase in mound height with altitude, from 0.55 m at 1864 m through 0.79 m at 2079 m to 0.85 m at 2657 m, although dimensions are considerably modified by slope of the ground surface to the extent that mounds on steeply sloping ground at high altitudes do not differ significantly from those at low. This presumably reflects the fact that conditions do not facilitate the settling of cold air. Minimum vine height varies much in the way that overall dimensions of the mound do, averaging 0.24 m above the ground surface at 1864 m and rising to 0.64 m at 2657 m. Indeed, the entire arrangement of planting changes. Thus at lower altitudes vines are planted over the whole upper surface of the mound, but above about 2400 m a technique termed *moró* is used. Here the vines are arranged concentrically in such a way that tubers develop only within the circle and therefore at the very top of the mound. Both modifications are made in recognition of the fact that "ice" will destroy the sweet potato if it is planted too close to the ground surface. Finally, while at lower altitudes the soil is worked into a fine tilth, in the upper zone of settlement mounds are formed from coarse clods of earth which are then simply covered with a finer soil. This practice presumably serves, at least incidentally, to produce a soil which is less well aerated, therefore reducing the likelihood of significant fluctuations in surface temperature at altitudes where even slight variations might be critical to plant growth.

Mounding serves, then, as an effective adjustment to mild inversion frosts such as occur when screen temperatures drop to around freezing point. For the Central Enga (Mae and Raiapu) resident in the Syaka and Middle and Upper Lai valleys it is an entirely satisfactory means of coping with the hazard. At higher altitudes, however, frosts are occasionally much more intense, as well as being more persistent. During the recent series, for instance, in excess of 25 nights of ground frost[4] were experienced at Iumbis in the Upper Wage valley (about 2620 m) and the lowest recorded screen temperature was −2.3°C. Under these conditions, mounding *per se* is rendered ineffective, the depth of the inversion frost greatly exceeding the dimensions of the mound. Thus the natural vegetation of the broad depressions in the Kandep area was damaged by frost up to 100 m above the valley floor. However, as the events of 1972 clearly illustrated, populations resident at these altitudes have additional ways of responding to the hazard.

[4] Calculated on the assumption that ground frosts were experienced whenever screen temperatures fell below 4.4°C.

THE FRINGE ENGA: A MODIFIED ADAPTIVE STRATEGY TO COPE WITH A MORE PERSISTENT HAZARD

From an ethnographic point of view, it is customary to draw a distinction between Central and Fringe Enga. The former are resident in the Wabag-Wapenamanda area (the Lai and Syaka valleys), are characterized by high population densities, and conform to what is generally recognized to be the New Guinea "norm" in that they can be viewed as comprised of a large number of locally organized populations – small discrete groups having intimate and exclusive relations with their immediate environment. They reside between about 1500 and 2200 m on dissected terrain and therefore experience only the occasional, mild frosts that are coped with in the manner described above, i.e., entirely within the bounds of their group territories. The Fringe Enga live, for the most part, at much higher altitudes (2300–2700 m) in the broader valleys of the Marient, Lai (Kandep), Wage, and Lagaip, centering on the government stations of Kandep and Laiagam. And conventional wisdom has it that they are for the large part simply refugees from the Central Enga: hapless individuals who eke out a miserable existence in a hostile environement.[5] That is, they live in essentially the same way as the Central Enga but much less successfully on account of the severity of the frost hazard. This view has been developed principally in the writings of the anthropologist M. J. Meggitt and subsequently reinforced by government officers (public health and agricultural officers) concerned with the area. While some of their observations, e.g., regarding Central Enga origin and inferior nutrition, are undoubtedly correct, the interpretations given tend to be highly ethnocentric (to the Central Enga) and therefore misleading. Thus at one level Fringe Enga nutrition must be viewed in light of the possibility that the prevailing environmental conditions at higher altitudes reduce exposure to infectious diseases and therefore the need for more ample nutrition. More important, whatever the origins of the population, the events of 1972 clearly demonstrate that the high-altitude Fringe Enga adapt to their environment in a substantially different way than do their kinsmen at lower altitudes. In particular, in terms of strategy the notion of adaptation being achieved almost exclusively at the local level–of closed corporate communities–proves to be a highly inappropriate and misleading one. The reality is far more complex.

For these high-altitude populations, the frost hazard is much more persistent; minor frosts are experienced almost annually, while more serious, killing frosts occur every one to three decades. It is possible in turn to identify three distinct levels of coping with the problem – levels that may be called local, intra-

[5] Meggitt (1972: 117) writes, for instance, that the Kandep was "until the recent construction of roads little more than a vast series of cold swamps at about 7,500 ft. [2313 m] above sea level, punctuated by drier hillocks on which small communities huddled and grew inferior sweet potatoes."

regional, and extraregional. The first refers to the strategy adopted within the boundaries of the group territory; the second refers to that within the immediate region, i.e., an area which shares similar ecological and particularly altitudinal characteristics; the third refers to the exploitation of resources at some distance from the local group territory and in a much more favorable ecological context, where the first hazard is nonexistent.

The Local Level

The fringe populations of the Kandep area (Marient, Lai, and Wage valleys) practice mounding as their exclusive method of cultivation. In this respect, they distinguish themselves markedly from the Raiapu (Central Enga), who have three types of gardens, only one of which is mounded. Further, virtually all food crops are planted on the mound, their actual arrangement over the surface reflecting variations in frost tolerance. Thus sweet potatoes are arranged concentrically around the top while the more quickly maturing and slightly frost-tolerant "Irish" potatoes (*Solanum tuberosum*) that have been introduced within the past 20 years or so are planted (or simply spring up) randomly over the whole surface. Similarly, other recent plant introductions with a moderate to high resistance to frost, such as peas (*Pisum sativum*), beans (*Phaseolus vulgaris*), and cabbage (*Brassica oleracea*), are confined to the lower parts of the mound below the circle of sweet potato vines. In this way, maximum advantage is derived from the cultivated area given the constraints under which agriculture is practiced.

In addition to this particular variation in cultivation techniques, gardens are generally maintained in two ecological niches (Fig. 3). Within each group territory, there are two major terrain units of agricultural significance, the valley bottoms and the lower slopes of the dividing ranges, with settlement being concentrated along the margins of the two. The bottom lands are typically under grass while the slopes are under primary and secondary growth that is progressively being converted into grassland as a result of clearing for cultivation. From the point of view of agricultural productivity, it is the former that are preferred, the soil being more fertile and having less tendency to dry out. The land is in turn cultivated much more intensively, fallow periods being limited to 1 or 2 years' duration. Nevertheless, one serious disadvantage arises from the location of gardens in the bottom lands — they are very vulnerable to frost. Hence, while the vast majority of gardens are concentrated in the depressions, many households have one or two on the slopes. Here, elevation above the valley bottom, improved air drainage, and the shielding effect of the surrounding forest together significantly reduce the gravity of the hazard. These latter gardens, while mounded, are cultivated on a somewhat different cycle. There are two successive plantings, with emphasis in the first being placed on various minor greens (*Rorippa* sp., *Brassica ?campestris,* etc.) and in the second on the staple, sweet

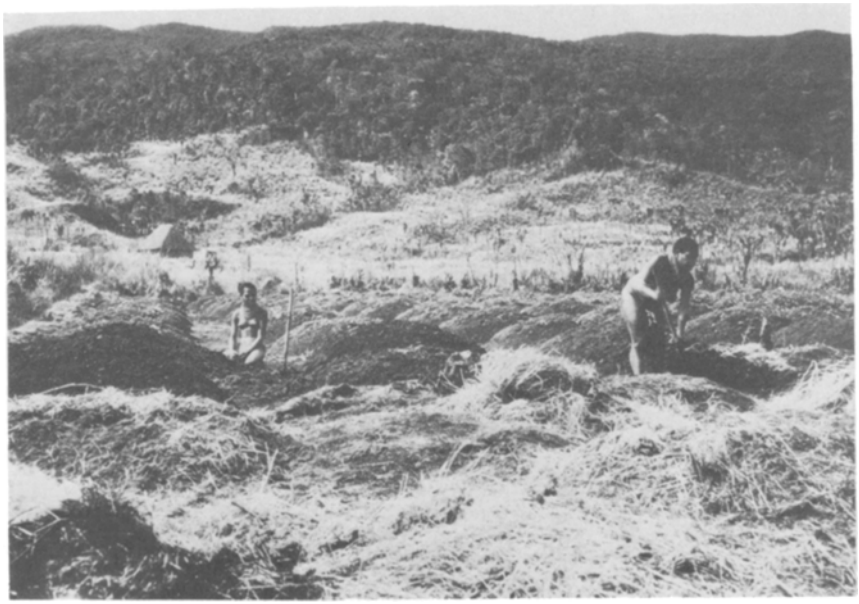

Fig. 3. Within each group territory, food gardens are maintained both on the bottom lands and in small forest clearings on the hill slopes.

potato. In both, taro (*Colocasia esculenta*) is an important subsidiary crop. Thereafter, the gardens are abandoned more or less permanently, apparently because production falls off very rapidly. Since they are initially cleared from forest, this practice facilitates the progressive upward shift of the forest-grassland boundary.

This spatial arrangement of agricultural activity enables the population to cope with the minor killing frosts that are experienced every few years, because even though serious damage may be incurred in the depressions the slope gardens are left more or less unaffected. Thus in addition to food being continuously available there is, more importantly in the long run, a readily available source of planting materials, allowing recultivation of the damaged gardens to commence immediately.

Further, in addition to these long-term measures, a few people take preventive action immediately prior to an expected frost. A few mounds may be covered with grass or other plant material, all but the very tip of newly planted vines may be temporarily covered with earth, or the grassland in the center of the broad depressions may be set on fire. However, no one views these as satisfactory alternatives to serious agricultural planning. And here, because of the possibility of serious frosts occurring that will do massive destruction to foods and planting materials in both niches at the local level, most households are

concerned with maintaining access to resources located at considerable distances beyond the boundaries of their particular group territories.

The Intraregional Level

Many members of each local group exercise outright and/or usufruct rights to land in two separate locations that may be as much as 1 day's walk from each other but still within the confines of the high frost risk area, i.e., within the same or adjacent valleys and at similar altitudes (Fig. 4). Usufruct rights are obtained to land of affines and normally maintained by death compensation payments, while outright access reflects the fact that many clan territories are geographically fragmented. Thus those belonging to the Aimbirepe and Agulya phratries control land on both sides of the Marient basin, while members of Ku and Molopai, principally situated at the head of the Lai (Kandep), also have territory in the Upper and Middle Wage valley. In 1973, at least one-third of the members of Wesanda (at Tinjipaka in the Marient) and Bipe clans (at Iumbis in the Wage) were maintaining access to nonlocal land in this manner. On account of it, two houses are generally maintained and a great deal of time is spent in moving

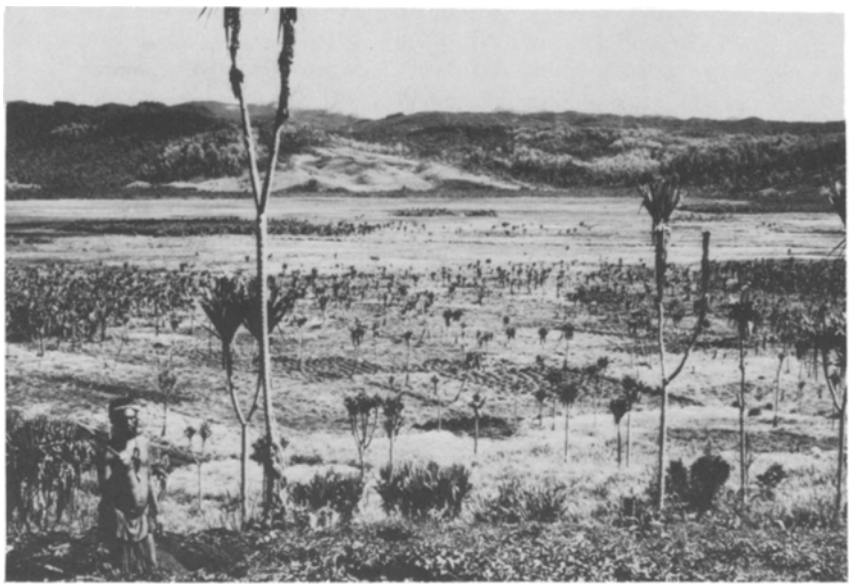

Fig. 4. Individuals frequently maintain gardens on different sides of the broad depressions in order to counter the varying effects of slope and aspect on frost distribution and intensity. Note the abundant stands of pandanus.

between the two locations in connection with garden work. However, under "normal" conditions gardens are not necessarily maintained in both areas.

Whatever the explanation for this territorial "splitting" at the clan level and parallel partial separation in agricultural activity, it makes good sense ecologically in spite of the fact that the frost hazard is uniformly high throughout the region. While there is little empirical evidence to support the fact, it is clear that severe frosts do have a variable impact; altitude is not the only factor determining their gravity. Both their intensity and duration are influenced by topographical considerations of slope and aspect, the one affecting the movement and accumulation of cold air and the other determining how long a given area is protected from the direct rays of the morning sun. In the case of the first, the flow of dense air is strongly influenced by watercourses which facilitate its concentration as it moves downslope, and by low ridges which permit movement from one valley to another. As far as aspect is concerned, nocturnal frosts probably persist longer on westward-facing slopes as a result of their being in the shade for half an hour or more after sunrise. Such minor intraregional variations as these may be of critical significance for plant growth under conditions in which temperatures drop only marginally below freezing and are of limited duration. Within a single altitudinal zone, serious damage may be inflicted on gardens in one locality while those in another remain largely untouched. Householders thus have every reason to maintain widely separated agricultural holdings.

Even in the case of total loss of food crops, this geographical separation often makes good sense. Given that most crops are vegetatively planted, in the long run it is the lack of planting materials which is the gravest problem the affected populations have to face. Failure to start reestablishing gardens immediately can mean extending the crisis by several months if not indeed also intensifying it. Thus, while the sweet potato tubers continue to be available for 1-2 months following killing frosts, the growing plants themselves are permanently affected.[6] In the circumstances, proximity to unaffected areas outside the region as alternative sources of planting materials becomes critical. In general, the maximum carrying distance for sweet potato vines is one day's walk. This is because, unless well protected by grass, they dry out very quickly and many are lost. More important, they are bulky, and an adult is unlikely to be able to carry more than enough to plant three or four mounds. However, not all the high-altitude zone is immediately adjacent to areas unaffected by intense frosts. For

[6] In a survey carried out through the Kandep area immediately following the killing frosts of October 1972, informants repeatedly made statements similar to the following (in Pidgin English): "olsem mipela kisim inap kaikai nau, tasol taim bilong ol pipel i dai long hangri ino yet. Dispela taim nau ino taim bilong ol pipel i dai. Taim bilong pipel i dai ino kam yet" (Lacey, n.d.:1). ("We nevertheless get enough sweet potatoes at present; this isn't yet the time when people die from starvation. Now isn't the time when people die. The time when people die hasn't come yet.")

Fig. 5. Sweet potato vines being carried into the Marient from the Upper Mendi valley.

instance, Tinjipaka, on the northern side of the Marient, is at least 2 days' walk from the Syaka valley, an area that does not experience severe frosts. On the other hand, the other section of Wesanda clan's territory, at Pulya in the south-west corner of the basin, is within a day's walk of the Upper Mendi and Kanba valleys, both major sources of vines in the event of widespread killing frosts (Fig. 5). Thus, on such occasions, many clansmen simply move to that part of their territory situated closest to the source of vines and commence replanting there. Significantly, all adults regardless of sex participate actively in the task. Six months or so later, as these new gardens approach maturity, vines are taken from them to the more remote territorial segment to initiate replanting there. The only alternative to this process of progressive reoccupation of the high-altitude areas is simply to wait until regrowth occurs in the damaged gardens. This is not

always certain and involves extended dependence on an alternative supply of food.

In the event of extensive killing frosts, widely displaced clan holdings certainly facilitate rapid reestablishment of food gardens. However, there are inevitably several months when no major foodstuffs are available and an even longer period when they are in short supply by virtue of the time taken to replant with vines carried in exclusively by foot. Furthermore, at these high elevations the sweet potato takes at least 9 months to mature. In the circumstances, more direct recourse to extraregional resources is dictated, and this takes the form of out-migration.

The Extraregional Level

On at least three occasions within living memory (in the early 1920s, in 1941, and again in 1972), a long series of frosts resulted in the massive movement of population down to lower altitudes. Entire families, together with their livestock, sought refuge in valleys sometimes situated as much as 7 days' walk away across the mountains, namely, in the Syaka and Lai (Wabag), the Ambum, Maramuni, and the Lower Lagaip valleys, and in the Porgera, Tari, Mendi, and Tambul areas (Fig. 6). While such out-migration represented, for those involved, a final recourse resorted to only some time after the certain destruction of food gardens, it was in no sense unplanned or haphazard.

The procedure on the first two occasions was, as repeated frosts resulted in increasing crop losses, to slaughter progressively most of the domestic pigs. This served both to reduce the demand for available resources (because pigs are partially dependent on cultivated foods, especially sweet potato tubers and vines) and to provide an important, if temporary alternative source of food that was particularly valuable because of its high protein content. At the same time, household heads made gifts of meat and livestock to kinsmen and friends living at lower altitudes, and also made progressive forays out, with the aim of locating hosts. Then, 1-2 months after the final frosts, when remaining staple food supplies had been exhausted, massive out-migration occurred. Following the move, migrants were given food and rights to mature gardens. Then cultivation rights were granted, and, in the case of those intending to stay several years, an invitation to build their own houses was extended. Once the family and remaining livestock were established at lower altitudes, the men commenced moving constantly back and forth between the host and affected areas, to harvest pandanus nuts, check on the recovery of gardens, replant, etc. Occasionally they might be accompanied by other members of the family, but outright return occurred only when sufficient gardens were back in production. In the circumstances, they might remain with their hosts for as little time as 6 months or for as long as 3 years. On the other hand, they might never return.

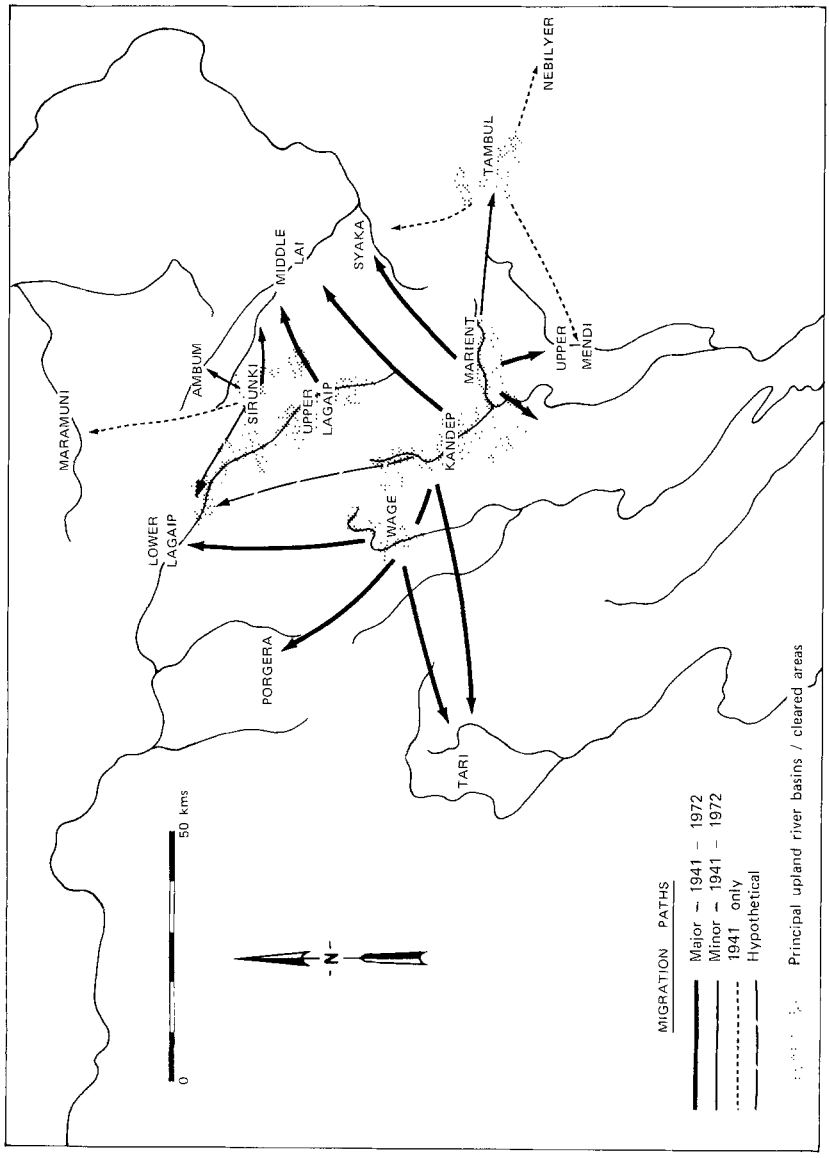

Fig. 6. Migration routes, 1941 and 1972.

The length of absence normally depended on such considerations as the extent of spontaneous recovery of gardens, the availability of planting materials, and the time taken for crops to mature, or, in other words, the altitude of the gardens, severity of the frosts, and proximity to unaffected regions.

From an adaptive point of view, what is significant about such out-migration is that it is a structured and carefully articulated respose to severe frosts founded on an elaborate fabric of social ties linking high- with low-altitude populations. The Fringe Enga differ from the Central Enga not only in terms of population size and density (both of which are low by comparison) but also in certain basic properties of their social system. As Lacey (1973) clearly illustrates, the former tend to be characterized by widely dispersed rather than compacted phratries. In other words, branched agnatic ties linking high- with low-altitude populations are common. Several clans in the southern Marient, for instance, have fraternal ties in the upper Mendi, others in the Kandep and Upper Lagaip with the Lai (Wabag), the Wage with Tari, Porgera, and the Lower Lagaip, and finally some Sirunki clans with the Ambum, Maramuni, and Lower Lagaip. In addition, marriage patterns tend to assume the same directional and altitudinal biases. Thus neither propinquity (distance decay) nor rules designed to spread affinal ties are so pronounced as among the Central Enga.

As may be expected, such ties are constantly being reinforced through exchange of various kinds, and they are in turn obligating for both parties. Thus, as far as the frosts are concerned, they greatly facilitate the occasional massive displacements of population, displacements that are seen to be crucial to the long-term occupation of the high-altitude areas. Indeed, they might almost be construed as designed to respond specifically to this need. However, if Meggitt's assessment of the "quality of life" at high altitudes is retained, it is difficult to understand why the more privileged lower-altitude populations should have any interest in developing and sustaining such links. On the one hand they are better endowed with resources and are not exposed to any serious environmental risks, while on the other they suffer from high population pressures. In effect, one would expect them to be actively concerned to prevent the development of any relationships that incur obligations.

In reality, the association is far from being one-sided: the frost-vulnerable populations possess or control access to a number of commodities that are highly valued by the Central Enga. The pandanus nut is a luxury vegetable food of major importance. The edible portion is of high nutritional value, particularly with respect to its protein and fat content, and is much relished by highlanders.[7] Depending on the variety, it may be eaten raw, cooked, or stored for many months if smoked. In consequence, it often enters into gift exchanges. Uncommon below 1800 m, it forms extensive stands in the high-altitude depres-

[7] The estimated food value for *Pandanus julianetti* is 588 calories, 10.7 g protein, and 59.0 g fat per 100 g (quoted in Waddell, 1972: 232).

Fig. 7. Pandanus nuts, from the Marient, being carried back to the Upper Mendi by the hosts of Fringe Enga refugees from the frosts.

sions and surrounding forests, while domesticated forms are planted in groves adjacent to settlements. The pandanus normally fruits during the period December-January-February, at which time entire households will take up residence adjacent to their stands, subsisting almost exclusively on the nut. Relatives are frequently invited to assist in the harvest. From the point of view of severe frosts, the timing of the harvest is extremely significant, for it tends to coincide with the period of maximum food scarcity, and those that have sought refuge at lower altitudes will commonly return for the harvest with their hosts, who are only too keen to supplement their own protein-deficient diets (Fig. 7).

Although the pigs bred in the high-altitude fringe areas are relatively few in comparison with the situation among the Central Enga, they are well known for

their superior body weight and the quality of their meat. The common explanation provided for this qualitative difference is the excellent foraging provided by the swamplands situated in the center of the depressions. It is in turn believed that, on account of their improved nutrition (they are dependent on domestic foods to only a limited extent), the pigs mature more rapidly. Lower numbers — pig:human ratios probably never exceed 1:1 among the Fringe Enga compared with a peak in excess if 3:1 among the Central Enga — may well reflect a situation where major distributions occur with comparative frequency (every 2-3 years) and there is no complex and more infrequent ceremonial exchange cycle, analogous to the *te,* operating at the regional level.

Irrespective of whether it is grounded in myth or reality this reputation that the high-altitude pigs have results in a constant and insatiable demand for them among the Central Enga. Because of it, refugees find no difficulty in obtaining hospitality in exchange for livestock.

Apart from having resources of their own which are highly desired by the Central Enga, people of the Kandep area have until recently acted as middlemen in the distribution of certain major traditional trade goods through the Western and Southern Highlands Districts. Four commodities that were, and to some extent still are, handled by Kandep people are sodium salt, "tree oil,"[8] a wide variety of sea shells, and stone axes. The first is obtained from springs at Murisosa near Sirunki and serves as the exclusive source for the Southern Highlands. The second originates from the Lake Kutubu area, and the third from the Gulf of Papua, where both are passed on to the Enga by Mendi speakers. Finally, stone axes were obtained from Ialibu. In terms of the proportion of total trade of tree oil and salt, the Enga speakers of the Marient, Kandep, and Wage valleys undoubtedly handled a major share. In the case of the other trade goods, the Central Enga obtained most of their supplies through the Tambul and Minyamp valleys. However, in all cases, demand was never satisfied and hence, even in cases in which their role was a minor one, the high-altitude populations profited from serving as agents in the distribution of essential commodities.

Yet to the Central Enga the most elementary and perhaps the most vital commodity offered by the high-altitude groups was people, or, in other words, potential allies and recruits to the local group. As I have stressed elsewhere (Waddell, 1973), local groups among the Central Enga are small in size and the lineage system renders membership potentially restrictive. Viewed against the perspective of a quasianarchic political environment, high population pressure on resources, and the obvious fact that natality and mortality rates vary significantly from one group to another over time, it is evident that the survival and good functioning of individual local groups are continually being threatened. Invariably there are some which are short of people, and for them it is axiomatic

[8] A vegetable oil obtained from *Campnosperma* sp.

that equilibrium (in terms of population size and density relative to that of their neighbors) must be restored as quickly as possible. Here, an event such as severe frost at higher altitudes provides a welcome opportunity. In effect, individual groups among the Central Enga *actively* solicit immigrants in spite of the fact that overall densities and pressures on resources are high compared with the fringe areas.

Because of this potential or actual, *continuing* value of maintaining close relations with high-altitude populations, migrants are invariably well received when they move down to lower altitudes. The violence and warfare that characterize highland populations and are often stressed for the Enga are in fact confined essentially to relations with immediate neighbors where each group is posing a constant threat to the survival of the other. Such threats do not characterize long-distance relationships, since there is no risk of one group expanding its territory at the expense of another.

Both parties then are interested in developing and maintaining ties, each for different reasons. But while for the Central Enga only a few (the most wealthy) seek systematically to develop long-distance connections and others are content to interact with their immediate neighbors, *every* Fringe Enga is explicitly concerned to "open roads." The reasons for this desire are obvious. Those without ties must pay dearly for their hospitality in the event of having to seek refuge elsewhere. It is not surprising, then, that most household heads in the high-altitude areas can claim among their primary kin at least one individual who is resident in or originates from an area not subject to serious frosts.

DISCUSSION

The obvious conclusion to be derived from this overview of Fringe Enga adaptive strategies is that they possess a diversity of mechanisms designed more or less explicitly to cope with frosts of varying intensities. These several mechanisms may be conceptualized as a three-phased series built into the structure of the adaptation. Of these, the lowest (local) level is in constant operation, whereas the other two become progressively operational as the intensity of the climatic perturbation (frosts) increases. This situation is thus analogous to that described for war processes by Vayda (1974) and lends itself to analysis on the basis of the assumption that "successful human populations, like successful animal species, have evolved mechanisms for achieving at least rough correspondences between magnitudes of perturbations and magnitudes of responses to them" (Vayda, 1974: 190).

Such mechanisms permit the Fringe Enga to deal more or less effectively with even the severest of frosts that seem to be experienced about once every generation. Thus, of those individuals directly affected by them, about three-

quarters can, it is estimated readily migrate to lower altitudes and at least some of the remainder can "get by" while remaining behind.[9]

Because of their ability to "manage" the effects of severe frosts, linked in turn with the fact that historically they controlled access to a variety of highly valued resources, the Fringe populations do not share Meggitt's view of their being comparatively disadvantaged *vis-à-vis* the Central Enga, at least prior to and in the early stages of contact. Their adaptation is simply different: the frost-coping mechanisms demand a degree of mobility that is unknown among the Central Enga. Only "development" has endowed them with this inferior status because much traditional trading has been eliminated through the provision of more favored commercial substitutes and because, in the eyes of at least one resident of the Marient valley, the benefits are trickling through to them by a very circuitous route — "If only the Europeans had come directly to us from Moresby instead of via Hagen, Wabag, Laiagam, and Kandep!"

The Traditional Strategy as Modified by Developments Since Contact

What I have outlined thus far is essentially the customary strategy for coping with frosts, i.e., the traditional strategy as modified by certain changes in the subsistence economy but unaffected by direct intervention on the part of government and mission. In fact, this strategy was only partially implemented in 1972 at the extraregional level in spite of the fact that the gravity of the crisis certainly warranted massive out-migration. As indicated at the beginning of this article, the limited scale of migration was due in large part to the mounting of a relief program which envisaged fundamentally different solutions to the problem.[10] However, both the viability of and necessity for the extraregional strategy have been affected by various other developments in recent years.

As noted, migration has been greatly facilitated by widespread trade and exchange activities which in turn have served to create and sustain kinship ties. However, the progressive substitution of manufactured for traditional goods over the past 20 years or so has led to a very real attrition in these activities. The Fringe Enga no longer play an enviable middleman role in the distribution of stone axes and shells. Sodium salt trade has also experienced a major decline, while only tree-oil has no obvious counterpart in the modern commercial world.

[9] Scoullar (1971) arrived at similar conclusions for a specific populations, namely, some groups in the Lagaip subdistrict that experienced a localized but fairly intense frost in 1971. He estimated that of the 12,500 affected some two-thirds could readily migrate, while of the 3800 expected to remain behind over half would be able to survive on remaining food resources. In sum, less than 13% of the entire population would require government relief.

[10] See Waddell (1974) for a detailed treatment of this point.

In consequence, the Fringe Enga have less of interest to offer to their potential hosts resident at lower altitudes, and there is grave danger of declining interaction for all but a few. Affinal ties may in turn be weakened. All of this is making it more difficult to "open roads." On the other hand, the construction of an extensive road network and the operation of an increasing number of "business cars" (passenger-carrying commercial vehicles) on it certainly renders movement easier. Now, should the circumstances require, public transport can move large numbers of people to lower altitudes, and those who had hitherto been denied the opportunity of migrating because of poor physical condition can be included. Thus on the one hand some of the constraints on mobility have been removed, and on the other it is probably becoming somewhat more difficult to find hosts.

However, the traditional adaptive strategy has been more directly affected by certain plant introductions of varying degrees of frost tolerance. These render the resource complex as a whole less vulnerable and thus make migration less necessary or reduce its duration. Two plant introductions in particular are important, one for the pig population and the other for the human. Kikuyu grass (*Pennisetum clandestinum*), originally introduced into the highlands by the government to cover airstrips and road cuttings and, because of its high protein content, now used by the Department of Agriculture in cattle projects, grows widely through the high-altitude areas. Initially impressed by its suitability for covering ceremonial grounds, the Enga now value it highly as pig feed. Tolerant of the severest frosts experienced, it provides an excellent alternate food source for the livestock in the event of a crisis, and women systematically harvest it. In this manner, large-scale slaughtering of pigs becomes unnecessary, while any sweet potatoes that survive the frosts can be used exclusively for human consumption instead of having to be shared with the pigs, as was normally the case previously.

"Irish" potatoes probably entered the high-altitude areas through customary trade routes in the early 1950s. They now assume an important role in the subsistence economy as a supplement to the sweet potato; their principal advantages are a tolerance of mild frosts and a maturation period of 3-4 months, compared with 9 or more for the staple. So well adapted are they to local conditions that they are treated as a semi-cultigen, planted systematically only in new gardens or ones being cleared from a long fallow. Elsewhere, a substantial harvest from self-sown potatoes is obtained after the various greens and before the sweet potatoes reach maturity. The severest of the 1972 frosts killed the growing plants but left the tubers undamaged.[11] As a result, they continued to be available for consumption, and spontaneous recovery (through resprouting) led to a new crop

[11]This contrasts with sweet potato tubers, where rot quickly sets in, rendering them inedible within 1-2 months of the killing frosts, and earlier if rain occurs.

within 3 months of the final frosts at the time when, otherwise, the crisis would have been at its worst.

In addition to the Irish potato, there are several greens of admittedly limited importance that have diffused widely through the region in the past 20 years or so, again largely as a result of Enga initiative. These are the common cabbage (*Brassica oleracea*), Chinese cabbage (*?Brassica chinensis*), and a semicultigen, watercress (*Nasturtium officinale*). Finally, there are several "European vegetables" which are grown for sale but are as of yet of limited appeal for domestic consumption, namely, parsnips, peas, and beans. All these greens were unaffected by the 1972 frosts.

These various developments since contact have served collectively to diversify and strengthen the Fringe Enga subsistence food complex, which prior to contact consisted essentially of a sweet potato staple, some taro, sugarcane (*Saccharium officinarum*), *Setaria palmifolia,* and a few minor greens. The damage done to it by severe frosts is no longer quasitotal, and, much more important, the period without a major food source available is much reduced. This serves to mitigate what Scoullar (1972: 7) refers to as "the most critical period of food supply" which may be expected to occur "between 5 and 8 months after the frost." Previously, there was migration by all who were able to migrate, while those obliged to remain behind subsisted for many months on a starvation diet comprised of a few greens (both wild and cultivated) that recover within a month or so of the frosts,[12] plus the product of hunting and foraging in the forest. With an increase in the numbers being able to remain behind and subsist on a more adequate diet and with a reduction of several months in the *necessary* period during which the majority must resort to out-migration, a relative, although as yet limited, decline in the importance of the extraregional level of coping with the frost hazard is occurring.

Since the Fringe Enga themselves are entirely responsible for these modifications to their subsistence resource base, it can be assumed that this trend toward increasing sedentarization of the adaptive strategy will continue, irrespective of the form that any government intervention may take in the event of a crisis. To date, however, these observed changes, while indicative of future trends, are of no great material significance. With the sweet potato still the staple and most of the major subsidiary crops not frost-resistant, mobility at the intra- and extraregional levels continues to serve as a vital mechanism for coping with all but the mildest of frosts.

[12]The most important of these greens were *Solanum nigrum, Oenanthe javanica, Brassica ?campestris,* and *Commelina diffusa.* People also scavenged through the abandoned food gardens.

The Incompatibility of Customary Coping Mechanisms with Modernization

While the Fringe Enga themselves are changing their subsistence economy in ways that are reducing the necessity for the most extreme forms of mobility, externally induced developments are also contributing to a greater sedentarization of the population.

Since contact, a new institutional structure has been created and initial steps have been taken to integrate the local population into a cash economy. Postcontact political units comprise much larger populations than the traditional clan. These units are at once responsible to and served by a government — initially, an Australian administration and, since 1974, an independent government — concerned primarily with law and order, and health and welfare. In recent years, a degree of regional autonomy has been achieved in the form of local government councils and representation at the national House of Assembly. Christian missions, concerned principally with evangelization, have created similar but separate institutional structures centering on "mission" rather than "government" stations. Attempts have been made by both institutions to stimulate commercial crop production at the local level, in the form of cattle raising, pyrethrum production, and the sale of a variety of vegetables. Outlets for the money so acquired are provided largely through a developing network of local trade stores as well as a system of annual tax collection by the local government council.

Clearly, if these various enterprises are to function efficiently, the population must not be constantly shifting. Its stabilization is necessary for development. In view of this fact, it is not surprising that government and missions actively sought to discourage out-migration in 1972. Irrespective of World Health Organisation guidelines, they, as institutions, had a personal stake in retaining the affected populations in the disaster areas.

While this trend toward sedentarization may be irreversible, it is nevertheless important that the pressures exerted by external agencies do not exceed the capacity of the population itself to sustain the process. From an adaptive point of view, acting quickly to discourage mobility is not only unnecessary but also very expensive, as illustrated by the 1972 experience wherein the government had to assume full responsibility for the support of those victims of frost that they had persuaded to remain behind. Strictly speaking, to administrate and to proselytize are largely self-justifying acts. They bring limited tangible benefits to the population, and frost victims are in no sense denied these benefits in the event of their migrating elsewhere since all Enga are served by the government and one or another of the Christian missions. It is rather the commercial economy which, in a *measurable* sense, suffers from migration, through an immediate curtailing of production and entrepreneurial activities and through longer-term

effects on the investments already made. As far as the Finge Enga are concerned, however, this sector remains very poorly developed. Thus in the Lagaip subdistrict, pyrethrum is the principal local source of revenue, yet sales over the year 1971-1972 amounted to only about $120,000, with an additional $25,000 or so being earned from vegetable and beef cattle production. Even by highlands standards, such a level of commercial activity is slight for a population of 65,000.

It may reasonably be assumed from this that the form of intervention adopted in 1972 was inappropriate.[13] More seriously, in systemic terms its long-term effects are likely to have been disruptive rather than constructive on account of the active discouragement of the third phase of the response to the hazard, that of extraregional migration. Further, the gestures, along with other general transformations associated with the contact experience, are leading to the progessive attrition of the infrastructure that permits this extreme response.

It is evident that, in the event of future environmental crises, relief should be designed to supplement and strengthen customary mechanisms for coping with the frost hazard, rather than to undermine them. This requires familiarity with these mechanisms to a degree rarely found among government and scientific personnel. It requires also some commitment to improving the effectiveness of the mechanisms in the context of an evolving political and economic environment. The challenge is considerable, because we are only now developing the conceptual tools for gaining understanding of the relationships between the temporal dimensions of stresses and responses, and a colonial and Third World situation is not propitious to acting on the basis of such understanding. Thus the very disruptions inherent in a colonial situation mean that intervention is invariably geared more directly to the interests of the institutional structures and commercial enterprises than to the interests of the population at large.

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