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WEED INFESTATION AND ITS IMPACT ON THE PRESERVATION OF A JAPANESE-ERA CONCRETE BUILDING IN MICRONESIA

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High rainfall tropical environments are very conducive to luxuriant plant growth. While welcome for the management of tropical plant collections and botanical gardens, such conditions of plant growth can be detrimental to historic properties. This paper provides and analysis of the weed infestation of a Japanese concrete structure in Pohnpei, discussing the nature of the infestation, the origin of the seed material and the implications for management.

Historic properties do not exist in a vacuum but are sited in a both cultural and natural environmental space. The interaction of the site with its surrounding physical environment sets up both cultural values (through cultural landscapes) and sets up conservation management issues derived from the impact the physical environment will have on physical fabric of the site. Biological, chemical and physical decay are a consequence when the environmental conditions and the nature and fabric of the site do not mesh.

Many historic properties are perfect colonization grounds for plants. For the purposes of this paper we will espouse the generic definition of a 'weed' as a 'plant growing out of place.' With that definition, all plants growing on or in the former Japanese Agricultural Research Station Building on Pohnpei must be classed as weeds.

EFFECTS OF PLANTS ON CULTURAL RESOURCES

The effects of plants on cultural resources are varied, depending on the vegetation zone and type of cultural resources present. Many studies comment on plant impacts of urban trees on the foundations of buildings and the structural problems resulting from moisture stress (Biddle 1998; Randrup *et al.* 2001). Others, such as Goeldner (1984), argue that early weed infestations, before the plants grow large and thus potentially destructive, is a good indicator of the lack of, and thus need for, maintenance as well as an indicator of potential structural problems that otherwise might go unnoticed.

The setting of the site has an obvious influence on and recruitment of seed and spores and thus an impact on the nature and extent of weed infestation. But plant damage is not con-

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fined to suburbs and the rural areas. A Spanish study (Garcia Rowe *et al* 1991) found that a considerable number of plant species had settled in and on urban cathedrals. On occasion the historic environment can become a major refuge of plant species, which then sets up value conflicts over management. The study of fire-sensitive native grasses in surviving in rural cemeteries is well cited (cf. McBarron *et al* 1988), they in most cases do not interfere with the management of the sites. Claims have also been made that building substrates can become refuges for rare lichen and mosses, and that these should be preserved unless physically damaging to a structure (Ariño & Saiz-Jimenez 1996).

Vascular Plants

The effects of vascular plants growing at and near buildings have been addressed by a number of authors (for references to tropical situations see next section). Garcia Rowe *et al* (1991) found the following reasons for weed settling at, in and on historic sites:

- Human activity–Construction debris left behind
- Human activity–Lack of cleanliness
- Lichen and moss activity (bioalteration of substrate)
- Algae activity (bioalteration of substrate)
- Air pollution (chemical alteration of substrate)
- Artificial barrier allowing wind deposited soil/dust accumulation
- Localized humidity (corroding pipe)

The main impact derived from vascular and non-vascular plant growth is two-fold: i) the development of microclimate and the retention of moisture long after rainfall has ceased (through shaded environment and dripping leaves) and physical impact due expanding root and stem diameter. This is particularly so in the case of ivy and figs.

Microflora

Lichens and algae growing on stone cause structural decay by the penetration of the lichen's thallus and algae's polymer sheaths into pores and the expansion and contraction due to moisture variations (Monte 1991; Jones & Wilson 1985; Palmer 1991). In addition, CO_2 is emitted by respiration of the lichens and oxalic acid produced causing degradation of concrete and limestone substrates.

Apart from the biochemical alteration of the building surface and the disfiguring colonisation by lichens and algae, root penetration is a major source of concern (Govi 1991; Feilden 1994, p. 132).

Effects of plants in tropical environments

Tropical environments with their rampant plant growth are not very conducive to the preservation of cultural materials. In a study of the impact of tropical vegetation on sites in the Marshall Islands, Spennemann and Look (1994, 2006) demonstrated that the impact of vegetation is both physical, through penetrating roots or dropping elements such as coconuts, and chemical, through creating conditions favorable to the establishment of corrosion cells caused by ongoing moisture retention as well as by chemical reaction from decaying leaf and fruit matter. That study was largely confined to the impact of vegetation on heritage items made from metals, such as coastal defense guns and aircraft wrecks (Look & Spennemann 1993, 1998).

Some of the tropical vegetation can be impressive in its growth in, on and over historic sites. While destructive, it also adds to the mystique of ruined cities, which appeals to public imagination (Winter 2002). The ruins of Angkor Wat (Cambodia) are a good example where conservation needs and the visitor expectations need to be meshed (Sanday *et al.* 2001, Winter 2002).

When engulfed in vegetation with just the upper sections of the building protruding, event he Japanese Agricultural Research Station building under discussion here possesses aesthetic values as a ruins (see Figure 12 top).

While the infestation of sites with weeds is well acknowledged among historic preservation professionals working in the Pacific, only very little has been documented and published in that regard.

THE SITE AND ITS CONDITIONS

The former Japanese Agricultural Research Station at Pwunso, Nett, just south of Kolonia, Pohnpei State, Federated States of Micronesia, was designed by Yamashita Yasaburô, chief architect of the Japanese South Seas Bureau, and constructed about 1926-27 (Look 2006). Designed as a combined utility structure serving the Agricultural Research Station and the Meteorological Office of the [Japanese] South Seas Bureau, the building withstood the US bombing of Kolonia in February 1944 apparently undamaged. After the war the building served during the Trust Territory period both as the administration of the Agricultural Research Farm and later as government offices for the Department of Lands.

The Setting

The site is located on the grounds of the former Japanese and later the Trust Territory Agricultural Development Station and is surrounded by luxurious plant growth and a collection of tropical trees.

Moisture Regime

Given the environmental setting of the Pohnpei Agricultural Station, an island with high annual rainfall (average: 187.8 inches). The long-term monthly average ranges from 10.8 inches (February) to 18.4 inches (July). The level of precipitation fluctuates, with higher precipitation during El Niño/ENSO events.[1]

This rainfall, combined with between 77% (afternoon) and 90% (morning) average humidity, access to moisture is not a controlling factor of plant growth.

THE INVESTIGATIONS

In conjunction with a cultural landscape and concrete-preservation training course carried out by the US National Park Service in January 2006,[2] both the building and the surrounding grounds of the former Japanese Agricultural Research Station were documented and assessed. As part of the investigations of the building it was necessary to examine the extent and nature of the weed infestation and its impact on the preservation of the structure. The findings are described in this paper.

The investigations were limited to an assessment of the structure both from the ground and from easily accessible surfaces on and within the building. Given the advanced state of decay of some of the building fabric, care was exercised in accessing some locations for purposes of documentation of photography. The infestation with vegetation, as well as the levels of moisture were recorded and sketched in on building schematics that had been developed for the concrete preservation training course. For the purposes of this paper, the moisture levels well as the infestation with plant matter were plotted from these field notes on corrected CAD drawings.

By the time the vegetation was being documented, the majority of the plants had been cleaned off and/or cut back. This work had been carried out in preparation of the cultural landscape and concrete preservation training to be held. Despite the macro-cleaning carried out, there was still abundant evidence of the impact of caused by former (and in many cases still extant) vegetation. Additional information could be sources from photographs of the structure taken twelve months prior (January 2005). Some of these are reproduced in this paper.

DISTRIBUTION OF PLANTS

The distribution of the observed plants has been plotted on building outlines (Figure 4-Figure 5) and can be compared with the moisture levels observed. The classification of the moisture levels on the building was made through visual inspection only, classing the moisture into three groups (high, medium, low), which were determined by the darkness of discoloration on the stuccoed surface (Figure 2, Figure 3).

The *northern façade* shows medium levels of surface moisture along the upper sections of the central column as well as the first flanking bays, with a higher degree of moisture observed on the eastern side. Given that this is the direction of the trade winds, this differential is explicable. Low levels of moisture extend about half-way down the façade. Localised medium and high moisture regimes could be observed below the first-storey windows on the western section of the façade, as well as on the slightly protruding upper edge and the front door surrounds.

Figure 1. Colonization of a small crack by Microsorum scolopendria.

The infestation with plants on the northern façade is mainly derived from vegetation rooted in the surrounding soil. Although seemingly well cleaned, there is abundant evidence of the growth of former plant growth, especially with *Piper ponapensis*. While the plant causes little direct damage to the structure, it sets up a moist microclimate that will keep the stuccoed surface perpetually moist. This in turn makes it more susceptible to attack but by root matter intrusion of other plants. A good example for this is the colonization of a small crack by *Microsorum scolopendria*. While the root matter of the fern will not grow as much as would that of a fig, it will nonetheless expand the crack, thus allowing ingress of more moisture, and, importantly, windblown dirt. The latter, combined with moisture, will then provide fertile conditions for additional plant growth, especially the seeds of figs.

The *southern façade* exhibits strong plant infestation with artillery plant (*Pilea mycrophylla)* on both pilastered buttresses. The distribution of the plant matter on the façade (Figure 5) is closely correlated with the availability of surface moisture (Figure 3) brought about by lacking down pipes on the roof of the building.

The vast majority of plant infestation is superficial, mainly the artillery plant. Of concern, however is the successful establishment of a *Ficus tinctoria* on the southwestern edge of the building. The plant exhibits a somewhat compact growth pattern which cannot be explained unless the plant has been repeatedly cut back in the past. Some evidence of a great than apparent age of the plant is that it has been to send out aerial root tracers through a vertical crack/crevice between the concrete score and the stuccoed surface. That root emerges into the open about halfway down the building where it exhibited at thickness of ¾ inches. At the time of recording the root was still about four feet away from the ground surface. Once the aerial root has made ground contact it will be able to grow and thicken very rapidly. While the fact that it will cause the stuccoed surface to spall off is of mere cosmetic significance, the concern is that the plant will be able to penetrate other crevices and expand these.

The insidious nature of the matter is that the crevices expanded by the tree root will allow further moisture ingress through falling damp, which will accelerate corrosion and decay of the building fabric creating further hairline cracks which can be exploited by the plant.

Understandably, the infestation with plant matter is stronger where there are *flat surfaces* that are conducive to the build up of windblown soil and subsequent development of humic matter derived from decaying vegetation. As the area is colonized by vegetation, the plants act as additional wind breaks thus speeding up the settling of further soil.

A good example for this is the *Microsorum scolopendria* growing at the interface between the corrugated iron roof and the concrete wall surface on the western side of the building. The area is located in the lee of the trade winds, and we can assume some eddy effects just off the edge of the building. Moreover, the nature of the corrugated roof, combined with the stuccoed surface of the building would have trapped all wind-blown sediment. Once established, the *Microsorum scolopendria* added to the eddy effect trapping more soil. In addition, the sloping roof meant that all rainfall, no matter how small would have been funneled to the root mat of the ferns.

Offsetting these positive conditions for plant growth are that on the building under discussion the available surface are all concrete surfaces which make root penetration difficult (unless in areas of existing cracks or surface irregularities. That limits the possible impact. Despite these qualifications, it should be noted that the January 2005 photograph shows the existence of substantial *Ficus tinctoria* growing on the southeastern roof surface (Figure 12). At the time of recording the chopped-off base could be observed. Although only shallow rooted at the location (on the surface of the roof), the base stem diameter was already 6 inches. Once the roots had reached the base of the building and thus gained access to ground moisture and nutrients the tree would have caused substantial damage.

s.

Table 1. List of species encountered

Species	Ground, growing up walls	Outside walls	flat roof and overhang ledge	moist inner walls	cracks on drier walls
Alysicarpus vaginalis (L.) DC. (Fabaceae)			■		
Axonopus compressus (Sw.) P. Beauv. (Poaceae)			■		
Chamaesyce hirta (L.) Millsp. (Euphorbiaceae)			■		
Chromolaena odorata (L.) King & Robinson (Asteraceae)			■		
Chrysopogon aciculatus (Retz.) Trin. (Poaceae)					
Cyanthillium cinereum (L.) H. Rob. (Asteraceae)					
Davallia solida (G. Forst.) Sw. (Davalliaceae)		■	■		
Ficus tinctoria G. Forst. var. *neo-ebudicum* (Summerh.) Fosb. (Moraceae)		■			
Fimbristylis dichotoma (L.) Vahl (Cyperaceae)			■		
Ipomoea triloba L. (Convolvulaceae)			■		
Microsorum scolopendria (Burm. f.) Copel (Polypodiaceae)		■	■		
Pennisetum purpureum Schumach. (Poaceae)					
Phyllanthus tenella Roxb. (Phyllanthaceae)					■
Pilea microphylla (L.) Liebm. (Urticaceae)					■
Piper ponapensis C. DC. var. *trukensis* (Yunker) Fosb. (Piperaceae)	■				
Psidium guajava L. Guava (Myrtaceae)					
Pteris vittata L. (Pteridaceae)					■
Algae (at least 2 species):					
1 blue-green alga (Cyanobacteria)					■
1 yellow alga (Chrysophyceae?)					
Mosses (at least 2 species)					■

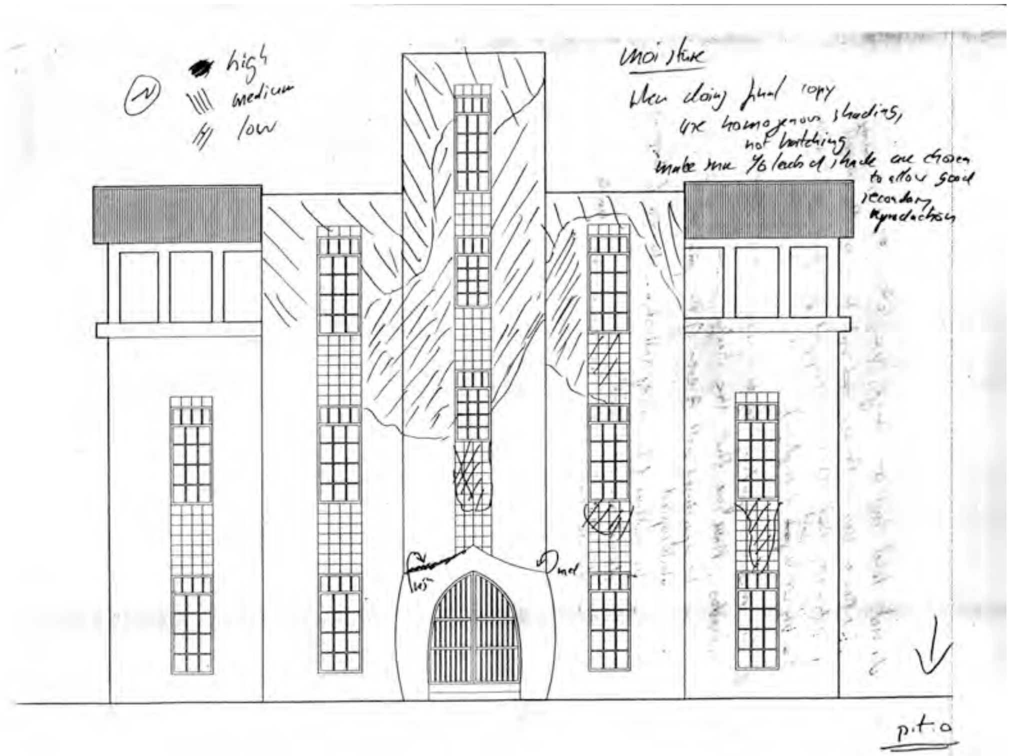

Figure 2. Distribution of surface moisture, northern facade of the Japanese Agriculture Building on Pohnpei

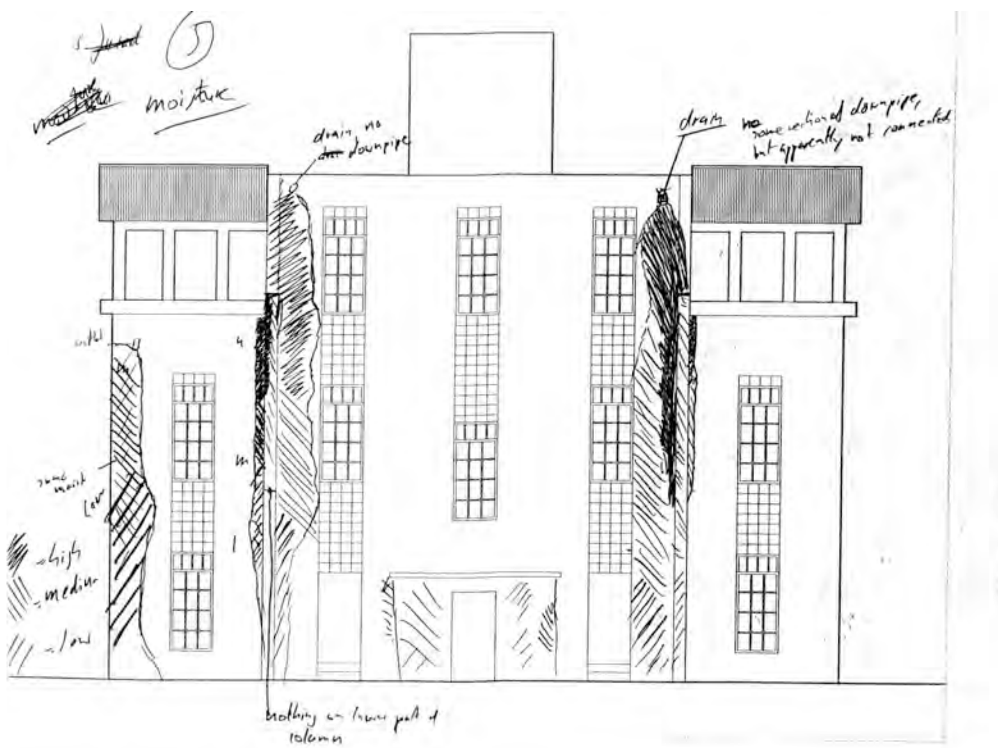

Figure 3. Distribution of surface moisture, southern facade of the Japanese Agriculture Building on Pohnpei

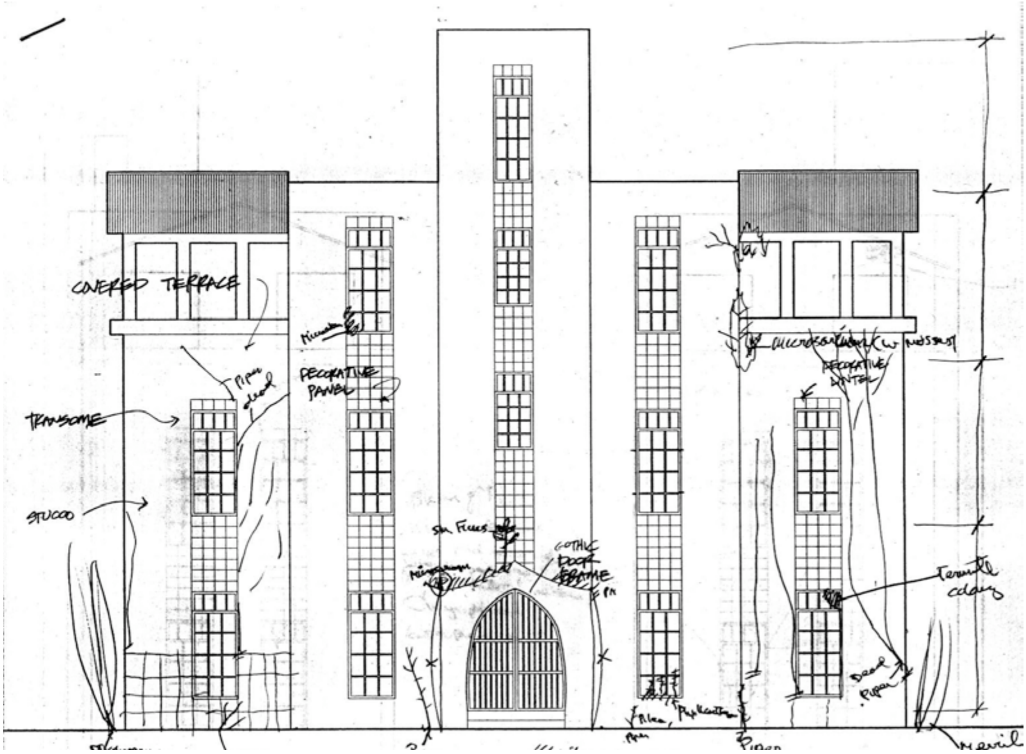

Figure 4. Distribution of plant growth, northern facade of the Japanese Agriculture Building on Pohnpei

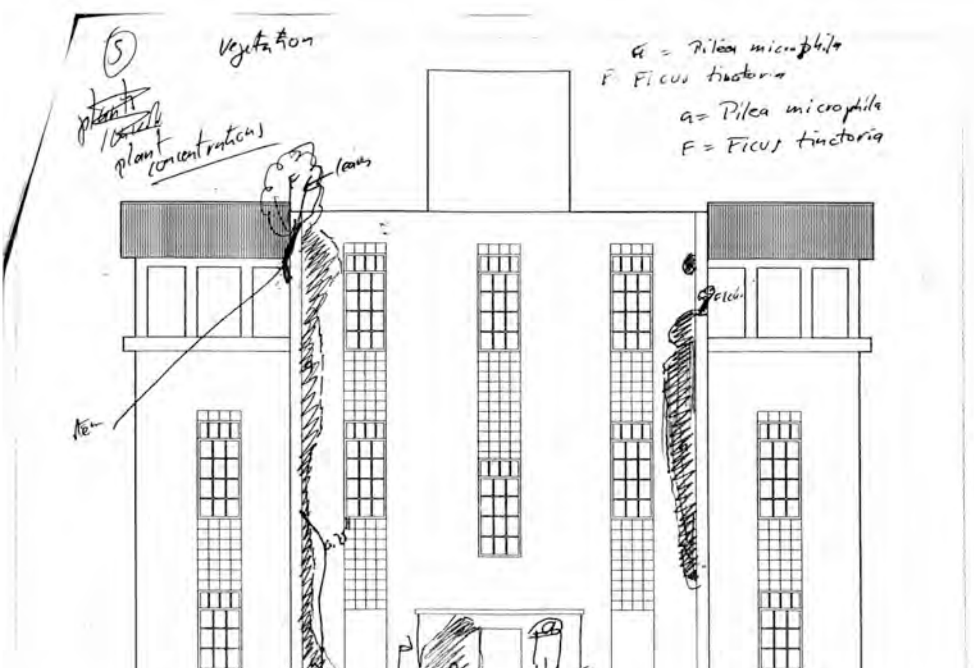

Figure 5. Distribution of plant growth, southern facade of the Japanese Agriculture Building on Pohnpei

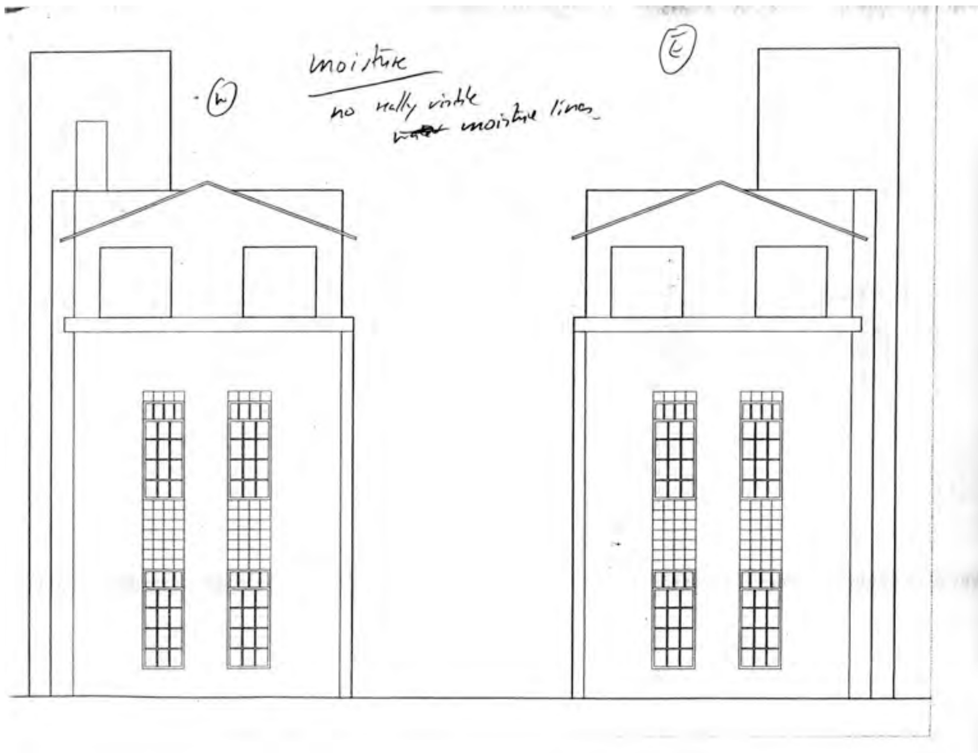

Figure 6. Distribution of surface moisture, eastern (left) and western (right) facade of the Japanese Agriculture Building

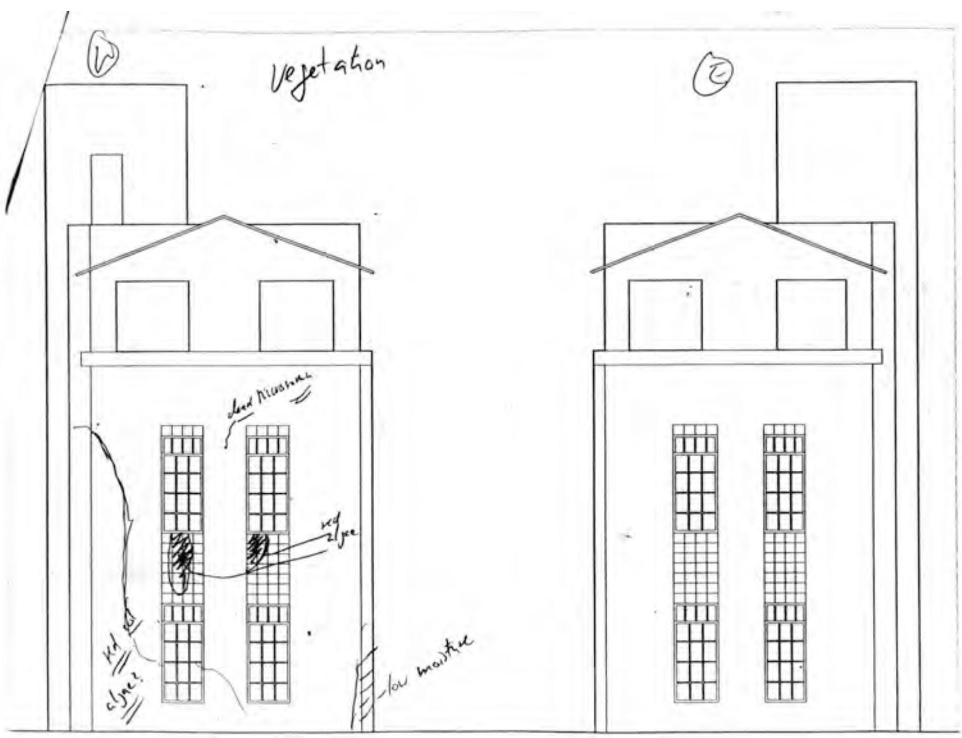

Figure 7. Distribution of plant growth, eastern (left) and western (right) facade of the Japanese Agriculture Building

Figure 8. Weed infestation at main entrance on the southern façade of the Japanese Agriculture Building November 1992

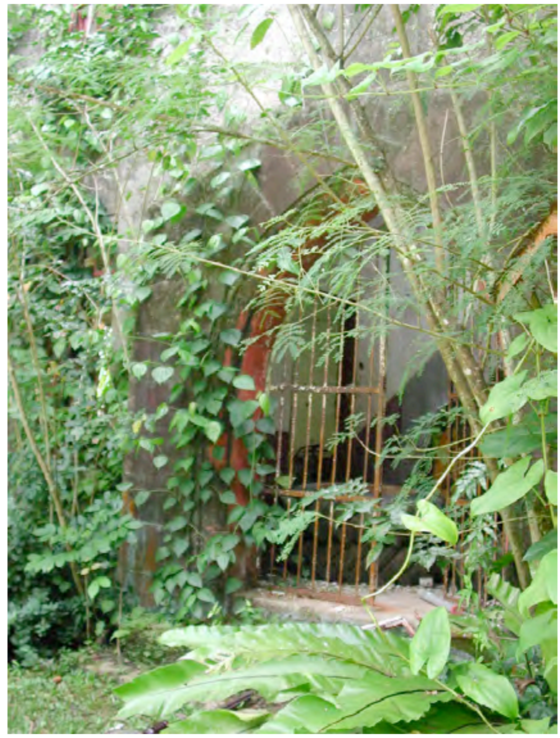

Figure 9. Weed infestation at main entrance on the southern façade of the Japanese Agriculture Building January 2005

Figure 10. Weed infestation on the southern façade of the Japanese Agriculture Building November 1992

Figure 11. Weed infestation on the southern façade of the Japanese Agriculture Building January 2005

Figure 12. Dense plant growth, even if rooted in soil and not the masonry, sets up a moist microclimate that retains moisture long after rainfall has ended. Top: northern façade; bottom: southern façade as photographed in January 2005.

The species recorded

Seventeen species of vascular plants plus at least two species of mosses and two species of algae were recorded growing on the walls and roof of the Japanese Agriculture Station building. Most species were growing on the outer walls, but two ferns, one moss, one alga, and a species of *Ficus* had become established on inner walls where light and moisture conditions permitted.

Table 1 lists the plant species observed growing on and in the building and their locations. In addition to plants growing up walls but rooting in ground, the following microhabitats were observed: i) outside walls; ii) inside walls; ii) flat roof and overhang ledge with accumulation of litter and debris, and iv) cracks on drier wall

Figure 13. Appearance of the southern façade at the time of documentation in January 2006.

Figure 14. Rapid recolonisation of the wall surface by the ground rooting Piper ponapensis *var.* trukensis.

SECONDARY PROBLEMS

In addition to the direct effects of plant infestation we need to consider secondary effects. These are mainly caused by the microclimatic conditions set up by the luxurious pant growth. The excessive growth of plants at the north-western side of the building (see Figure 12 top) set up perpetually shaded and thus perpetually moist conditions.

It was these conditions that gave rise to a termite infestation by species termites setting up a above-surface tunnel system on the external wall, including a nest in one of the window corners (). Had the wall been fully exposed to sunlight and thus drying conditions, that infestation is unlikely to have occurred.

Figure 15. Above-surface nest system of termites.

RATE OF INFESTATION

One of the concerns for site management is the rate of infestation and the speed of (re-)growth. No systematic studies have been carried out. Based on photographic evidence (Figure 8 to Figure 11) it is clear that bulk of growth occurred in the past dozen years.

All vascular plants, however, occur in the grounds of the gardens surrounding the site. Thus ongoing recruitment is not a problem leading to the specter of renewed infestation unless managed.

Figure 16. Above-surface tunnel system of termites.

MANAGEMENT ISSUES

There is a growing body of literature that examines the various management options available. Clearly, in the case of intentional plantings, such as ivy growing on facades, the removal of the impacting plant will actually diminish the aesthetic value of the property. Depending on the nature of the statement of significance that may or may not be permissible and needs to be weighed up against the extent of possible damage.

In this case any use of the structure requires that the surfaces of the building are accessible. According to the proposed conservation management plan 'preserved ruin' status is not desirable.

Clearly, not all species are damaging the structure in a like fashion. Some cause more cosmetic damage, such as the artillery plant. The potentially most damaging species is an indigenous fig, *Ficus tinctoria* var. *neo-ebudicum*, whose seeds are transported in bird droppings. Rainwater will often moved the seeds into 'safe' locations, such as corners, edges, cracks or crevices where they germinate. Once established, the roots of the young fig plant soon grow down to the ground enabling the plant to develop into a vigorous small hemiepiphytic tree. Considerable structural damage may be caused subsequently by the expanding roots and base of the plant, which are even able to split concrete mortar. For example, roots of one of the larger figs had grown down behind an outer concrete column, starting to cause separation from the main wall.

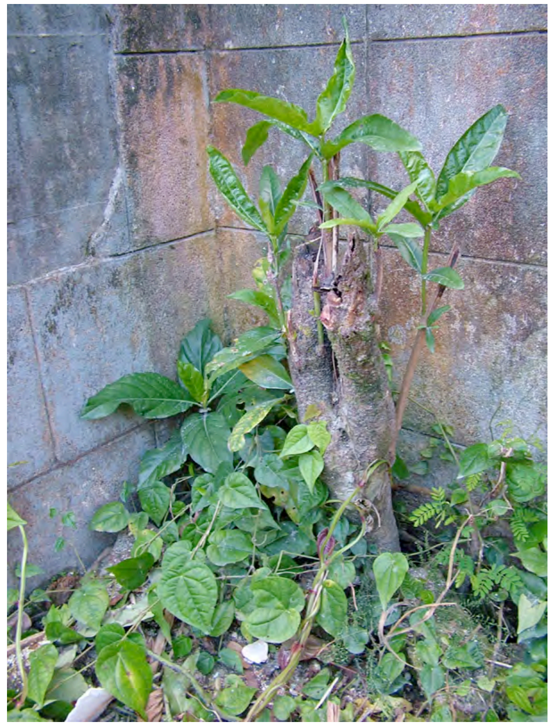

Figure 17. Cutting back vegetation has no lasting effect unless the stumps are poisoned. Two-week old regrowth at the base of the northern façade.

Maintenance of the building should include routine cleaning of accumulated debris and leaf litter and constant eradication of young plants and seedlings as they appear. An initial eradication of the algal growth is indicated. While chlorox bleach applied as a spray would control the algae and mosses very easily, it is necessary to assess the impact of the spray on the stucco (cf. Mouga & Almeida 1997).

IMPLICATIONS

The rate on infestation, as evidenced by the rapid regrowth and recolonisation of the recently cleared surface demonstrates (Figure 14, Figure 17) it is imperative that ongoing maintenance and management of the currently abandoned structure occurs if it shall not decay further while conservation management options are being developed.

ACKNOWLEDGMENTS

We are indebted to Dianne Ragone (National Tropical Botanical Garden) for the January 2005 images used in this report..

ENDNOTES

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