
PAPER 1: **POSTHARVEST HANDLING OF TROPICAL FRUITS IN THE SOUTH PACIFIC**

Steven J.R. Underhill^{1,2} & Satesh Kumar³

¹University of the Sunshine Coast, Locked bag 4, Maroochydore DC 4558, Queensland Australia.

²Queensland Alliance for Agriculture, Food and Innovation, The University of Queensland, St Lucia, Brisbane, 4000, Queensland, Australia.

³College of Agriculture, Fisheries and Forestry, Fiji National University, Koronivia, Fiji Islands. Email: salesh.kumar@fnu.ac.fj

ABSTRACT

While tropical fruits represent less than 20% of the net horticultural productivity in the South Pacific, they experience disproportionately high levels of postharvest loss. Much of this loss is concentrated at the market-end of the value chain. Inter-island fruit value chains and those associated with transient and opportunistic fruit harvesting practices are particularly vulnerable. When losses occur they are often significant (20% to 80%), but can also be unpredictable. Postharvest loss has been attributed to the combination of low-input fruit production systems, poor postharvest practices, unpredictable transport, and short product shelf-life. Highly seasonal production with ensuing sporadic market over-supply and resultant prolonged storage further elevates postharvest loss. Mitigating postharvest loss within fruit value chains has become increasingly important in recent years as Pacific Governments and donors seek to enhance horticultural exports and improve industry resilience.

In this paper, we discuss the current postharvest challenges facing fruit value chains in the Pacific, with a specific focus on small island developing states. We highlight the interconnectivity between pre-harvest and postharvest handling remediation, the implications of semi-commercial fruit value chains, and the importance of transport and market system contributors to loss. Further, we discuss strategies undertaken to remediate postharvest loss, highlight the need for increased institutional capacity building and conclude by proposing a series of targeted interventions aimed at better supporting Pacific fruit value chains.

Keywords: fruits, Pacific, postharvest, horticulture, food loss, food security

INTRODUCTION

Postharvest handling of tropical fruit crops has historically received little attention in the South Pacific. Much of the effort in support of Pacific fruit value chains has focused on improving agronomic productivity, environmental sustainability, genetic resource management, and improving natural disaster resilience (Chung, 1987; Taylor & Tuia, 2007; Stice et al., 2010; Nath, 2014). Given endemic production challenges, the nascent stage of many fruit industries in the region, and cyclic risks due to natural disasters, such an approach is justified. For the majority of fruit crops and markets in the Pacific, there is little information as to current levels of postharvest loss, which fruits are most vulnerable, or the critical contributing factors.

In the last ten years, there has been an increased awareness of the need to improve postharvest handling systems as Pacific Island countries and donors seek to enhance and diversify the horticultural sector. The emergence of several important fruit export industries (i.e., Fiji papaya and breadfruit) has seen many larger horticultural enterprises progressively adopt better postharvest handling practices (Stice et al., 2007; 2010; Sole et al., 2014). Similarly, smallholder farmers accessing expanding domestic market opportunities, particularly those associated with the tourism sector, have started to improve their postharvest handling and food safety

compliance (Berno, 2011; Underhill, 2013a). Most Pacific Island Government fruit and vegetable strategies now make implicit reference to the need for improved postharvest handling practice (AAACP, 2009ab; Solomon Islands Ministry of Agriculture and Livestock, 2015; Vanuatu Department of Agriculture and Rural Development, 2017). With many Pacific small island developing states also facing the added burden of high rates of non-communicable diseases and food security risks, improving postharvest fruit handling systems is now considered essential to developing resilient and nutritionally sensitive Pacific food systems (Hazelman & Pilon, 1997; FAO, 2017; Underhill & Singh-Peterson, 2017).

In this paper, we provide a commentary on the broad postharvest challenges facing the development of sustainable fruit value chains in the Pacific, with a special focus on small island developing states. We further discuss the effectiveness of strategies to remediate postharvest loss, and conclude with a series of targeted and country-specific postharvest research and development priorities.

CHALLENGES TO IMPROVING FRUIT POSTHARVEST VALUE CHAINS

On-farm practice

Given the profound effect that pre-harvest practices have on fruit quality (Arpaia, 1994; Hofman et al., 1997; Sams, 1999; Rehman et al., 2015), any effort to reduce postharvest loss needs to be inclusive of wider efforts to improve fruit production systems. Pre-harvest practices often have the greatest impact on postharvest quality, when product is grown under low-input and low-intensity production systems, or when production is based on species or cultivars that are poorly suited to local conditions. For much of the fruits grown in the South Pacific, such conditions are the norm. In tree fruits (such as mango and citrus) there is limited or no tree pruning, little pre-harvest disease control, inconsistent fertiliser application, and limited site selection or cultivar evaluation. While temporary fruit (such as pineapple, papaya, and melon) production practices are more consistent with other broad acre crops, they are still far from ideal.

Low-input production practices not only results in poor and highly variable fruit quality entering the value chain, but also shapes underlying smallholder farmer attitudes and behaviours. Having produced fruits on the basis of minimal farm-inputs, fruit farmers are often resistive to adopting better postharvest handling practices that necessitate added input costs (such as improved packaging). This attitude is particularly prevalent in fruit value chains sourced from village or community-based plantings involving sporadic or opportunistic harvesting. Unlike vegetable crops which necessitate a greater investment in time and resources, much of the fruit production in the Pacific still remains semi-commercial in nature. We are not implying that all Pacific fruit value chains are semi-commercial, there are numerous examples of large fruit-based enterprises (>10 ha) throughout the region (i.e., papaya, pineapple, and citrus). Rather, the disparity between commercial vegetable value chains and the predominance of semi-commercial fruit chains, means it is often more difficult to improve postharvest handling practice amongst fruit farmers.

Dysfunctional fruit production systems in the South Pacific can also create critical obstacles to improving postharvest handling efficiency. In Tonga, limited access to new fruit cultivars coupled with few commercial plant nurseries has resulted in much of the domestic tree fruit production being sourced from aging trees, leading to declining fruit supply, reduced product quality, and elevated postharvest loss (Underhill & Singh-Peterson, 2017). In Samoa, domestic fruit production is based on a limited number of cultivars creating a concentrated seasonal market supply, resulting in significant market loss, and economic disincentives for wider industry participation (Underhill et al., 2017). This inter-connectivity between pre-harvest and postharvest value chain efficiency is particularly prevalent in the Pacific. Low supply volumes

and few commercial-scale farmers mean that there are few options for markets to compensate for the implications of poor pre-harvest practices.

Improved postharvest practices alone cannot be expected to undo the implications of poor pre-harvest practice. Similarly, poorly adapted cultivars, aging trees, or seedling-sourced planting material, translate into lower fruit quality, a greater risk of postharvest diseases, and reduced fruit shelf-life. The critical first step in reducing postharvest loss within Pacific fruit value chains must involve the introduction of elite or better adapted fruit genetics and improved local capacities to smallholder farmers.

Transport

Most Pacific fruit value chains, excluding those associated with PNG, involve comparatively short intra-island transport distances. Inter-island and inter-regional fruit value chains do exist and involve substantial transport challenges (i.e., inter-island supply of pineapples from Luganville to Port Vila, Vanuatu can take up to seven days), but they only represent a small percentage of product sold into Pacific fruit and vegetable markets. A recent study by Underhill et al. (2017), noted that much of the domestically-sourced fruits in the municipal markets in Samoa travelled less than 20 km from farm to market. The main fruit production regions on Efate Island, Vanuatu are less than 30 km from the Port Vila markets. In Fiji, the Sigatoka Valley, a key horticultural center is only 170 km from the Suva markets. The comparative close proximity of many intra-island production regions means product commonly arrives within twelve to twenty-four hours. As municipal markets across the region tend to be based on small vendor trading space and limited in-market storage capacity, commercial value chains are further forced to supply small quantities of product but on a regular basis. Collectively, fruit value chain logistics involve small volume consignments being transported over short distances with comparatively rapid market through-put. The emphasis here is on transport speed and predictability. The implications of poor on-farm postharvest handling practice are lessened through rapid transport logistics and limited market storage. In Pacific horticultural value chains, anything that slows the supply chain down, adds increased complexities to the supply chain logistics, or reduces transport predictability, will have a disproportionately adverse impact on the level of postharvest loss.

While horticultural transport distances may be short they are often comparatively expensive. Accessibility to affordable transport is commonly mentioned as a key concern amongst all smallholder farmers. For more remotely located farms or value chains that require multiple modes of transport, high transport costs can be sufficient to impede smallholder farmer market participation. For example, it is not uncommon for fruit farmers on the island of Espiritu Santo, Vanuatu supplying the municipal market in Luganville to incur 60% of the net consignment value in transport costs.

Creating more cost effective horticultural logistics has been a particular focus of donors, with various potential strategies being articulated in recent Pacific fruit and vegetable strategies (AAACP, 2009ab; Solomon Islands Ministry of Agriculture and Livestock, 2015; Vanuatu Department of Agriculture and Rural Development, 2017). Much of the recent attention has centered on promoting various farm-cooperative models, an approach considered by Duncan and Sing, (2009) and Veit (2009) to be difficult to implement in the Pacific. We believe more could be gained if an alternative approach based on targeted support of nascent outer island and regionally remote fruit value chains was considered. Creating more viable inter-island fruit value chains often only necessitates better at wharf storage facilities or more cost efficient wharf to market transport. For example, in Vanuatu it can cost more to transport fruit consignments from the Port Vila wharf to the Port Vila municipal market (approx. 2.5 km), than it does to transport product from Espiritu Santo Island to Port Vila, Efate Island (approx. 350 km). Further, inter-island fruit supply chains into Port Vila often cease during the Christmas period as family

members based at the markets relocate back to their village, leaving few options to coordinate supply.

Markets

Once at the market, rapid market throughput is vital if postharvest loss is to be minimised. While there have been few studies to explore the implications of market vendor handling practice, Underhill and Kumar (2014) and Underhill et al. (2017), reported proportionally higher levels of postharvest loss of fruits (compared to vegetables) in Fijian and Samoan municipal markets due to prolonged market storage. The implications of market operations and consumer purchase behaviour as potential additional contributors to postharvest loss are also poorly understood. There is some preliminary evidence to suggest that efforts to improve municipal market infrastructure in some Pacific Island countries may have actually increased the amount of postharvest loss, due to poor market design, reduced consumer accessibility, and disconnects with consumer purchase behaviour trends (Underhill et al., 2017). We believe, how and where fruits and vegetables are sold in the Pacific, has a profound effect on the level of horticultural postharvest loss. It is interesting to note that while Pacific fruit and vegetable markets and the consumer-end of the value chain have received little attention by researchers, there have been disproportionately large infrastructure investments by Pacific Island Governments and international donors to “improve” them.

STRATEGIES AND APPROACHES TO REMEDIATION OF POSTHARVEST LOSS

Postharvest institutional capacity building

The need to strengthen local institutional postharvest capacity to better support farmers in the Pacific has long been recognised (Cocker, 2000; Rolle, 2006). A review of postharvest research, extension, and education capacity in the South Pacific highlighted ongoing critical failures and the need for increased investment to support local postharvest research, development, and extension capacity (Underhill, 2013b). In subsequent years, there has been some notable improvements, with the Fiji National University, the Scientific Research Organisation of Samoa (SROS), and the Ministry of Agriculture Samoa now having dedicated postharvest specialists. SROS is starting to emerge as a possible important regional leader in postharvest research and development in the South Pacific based on strong support by the Samoan Government and significant investments by international donors. In spite of these recent gains, wider postharvest institutional capacity in the region remains poorly developed.

It is impossible to over-state the importance of nurturing strong and enduring institutional postharvest capacity in the Pacific. To be effective, extension officer capacity and resources in postharvest horticulture need to be enhanced. To be enduring, the horticultural curriculum at key Pacific universities and colleges needs to be strengthened to incorporate relevant sub-tropical and tropical postharvest handling content, supplemented with postharvest resource material. We believe that any initiatives to enhance fruit value chains in the Pacific that do not include postharvest institutional capacity are unlikely to be enduring.

Translating Government strategies and policies

While many countries in the South Pacific have developed fruit and vegetable sectoral plans and strategies that place strong emphasis on improved postharvest handling practices (AAACP, 2009ab; Solomon Islands Ministry of Agriculture and Livestock, 2015; Vanuatu Department of Agriculture and Rural Development, 2017), most have struggled to translate this intent into practice. The reasons for this are four-fold:

-
1. With the exception of Samoa and Fiji, Pacific Island countries tend to lack appropriate technical postharvest expertise or associated postharvest infrastructure. The capacity to identify, prioritise and respond to technical postharvest challenges, risks, or opportunities simply does not exist. For many Pacific Island countries, this is symptomatic of limited undergraduate or postgraduate training in postharvest horticulture at the various regional universities and agricultural colleges. Unless greater emphasis is given to enhancing postharvest content of existing agricultural curriculum, the challenge of poor postharvest capacity and awareness will remain.
 2. Remediating postharvest loss increasingly involves the development of robust private sector-government partnerships. This is particularly relevant when it comes to key investments in postharvest infrastructure such as refrigerated storage, export disinfestation equipment, and fruit and vegetable markets. To date, inconsistent engagement with the private sector has led to resultant infrastructure not being fit-for purpose, built in the wrong location, lacking critical human resources to operate, or being operated or utilised in a manner inconsistent with private sector benefit. This is particularly relevant in the case of export market access, where Pacific governments are often economically unable to sustain disinfestation infrastructure, but equally unwilling to disinvest ownership or enter into public-private partnerships to resolve.
 3. Tackling postharvest loss often requires a coordinated and multi-government agency approach. Unlike horticultural production challenges which normally fit neatly within the mandate of the Ministry of Agriculture, strategies to improve postharvest handling practices necessitate a multitude of government and non-government stakeholders, many of which have little pre-existing collaborative contact. Given the close connection between postharvest loss and food security, initiatives such as the recently proposed Tonga Food Security Council may provide a pathway forward.
 4. In many Pacific Island countries, there is a declining trend in agricultural participation coupled with increased urban drift. For those that persist with farming, ongoing access issues to critical farm inputs, land access, affordable transport, and limited market opportunities create powerful disincentives for increased investment. These challenges can be particularly acute for fruit farmers. Morgan (2014) noted that farmers commonly perceived local consumers to be high-price sensitive, a view likely to further compound farmer resistance to added postharvest input costs.

Inappropriate postharvest remediation

In seeking to improve postharvest handling practice in the Pacific there has been an ongoing tendency to default to postharvest remediation strategies that have proven highly successful elsewhere (such as sub-Saharan Africa and Southeast Asia). To do so, overlooks the fact that Pacific horticultural production systems possess many unique bio-physical and socio-economic attributes that can negate or undermine the effectiveness of such approaches (Duncan & Sing, 2009). This is not to say that getting the postharvest basics right is not important, but rather the introduction of any technology or strategy to address postharvest loss needs to be tailored to the local situation, sympathetic to socio-cultural considerations, and respond to the real contributors of loss.

Socio-networks and relationships within Pacific value chains are often overlooked, replaced instead with the perception that smallholder farmers in the region are disconnected from markets and are impeded by poor market connectivity. While this is true in many fruit value chains especially those associated with inter-island trade, we need to be cautious in assuming this situation is the norm. Kumar (2017) in his assessment of Fiji farmer and market vendor relationships observed that many smallholder farmers have been supplying the same market vendors for at least 15 years and that they retain close and enduring relationships with a very small and select number of vendors. In many cases, these deep farmer-to-vendor relationships are based on ethnic or geographic commonality. There are also complex and sometimes

transient socio-cultural issues at play within Pacific agri-food value chains (Eti-Tofinga et al., 2017). Overlooking potentially long-standing value chain relationships on the premise that they don't exist is a common mistake amongst donors and researchers. It is essential to first understand the existing value chain operations from the bio-physical and socio-economic level before seeking to introduce perceived best-practice.

Given the multitude of postharvest challenges along Pacific fruit value chains, interventions that seek to solve postharvest problems that do not really exist would seem improbable. Low-input postharvest fruit value chains should benefit from even the most basic level of remediation. However, just because there is poor practice within a postharvest value chain, does not mean that it leads to tangible levels of postharvest loss or reduced product quality. For example, introducing improved packaging into value chains with low levels of in-transit loss, providing on-farm cool rooms where there are few reasons to promote farm storage, or exploring regional collection centres in locations where existing transport systems are well established. In the right context, such strategies can revolutionise fruit value chains in the Pacific. However, when applied inappropriately, these same technologies can inadvertently erode smallholder farmer profitability or disrupt existing value chain operations.

Postharvest research and development priorities to support Pacific fruit value chains

We believe that to enhance postharvest handling practice in support of Pacific fruit value chains necessitates:

1. Raising awareness of good postharvest practice
2. Better institutional capacity in postharvest extension and research
3. Better postharvest information access
4. Enhancing availability of elite fruit cultivars

One of the strategic advantages that the South Pacific has to achieving this outcome is the extensive international research already undertaken in support of sub-tropical and tropical fruits. The challenge now is to create an effective pathway to communicate, value-add, and build-on this knowledge and expertise. What has been lacking to date has been effective regional postharvest discipline leadership and coordination, a network of suitably trained postharvest extension staff, better regional access to practical postharvest extension resource material, and enhanced farmer access to new and elite planting material. In terms of more specific details, we propose:

1. The horticultural curriculum at the University of the South Pacific, Fiji National University, Solomon National University, and the Hango Agricultural College (Tonga) be reviewed with the aim of improving postharvest horticultural content.
2. The Scientific Research Organisation of Samoa becomes a Pacific Postharvest Centre.
3. Research and extension officers in Vanuatu, Fiji, Samoa, and Tonga receive further training in postharvest handling practice.
4. Fiji National University and the Fiji Ministry of Agriculture receive donor funding to establish a joint fruits, vegetables, and root crops postharvest laboratory.
5. Current and historical fruit varietal trial plots at the various Pacific Government research stations are audited and information made regionally available.
6. The Pacific Community's web portal expanded to provide better online postharvest resource information to Pacific extension officers.
7. Pacific Island Farmers Organisation Network receives funding to provide training and awareness of good postharvest practice.

CONCLUSIONS

The challenges facing Pacific fruit value chains are not dissimilar to those associated with Pacific vegetable or roots crops. However, high-seasonal production, the prevalence of low-input semi-commercial production systems, and a short product shelf-life makes fruit value chains particularly vulnerable to high postharvest loss. In many cases, we know how to resolve the multitude of postharvest handling issues observed. The issue is how to do so in a way which translates into economic benefit for farmers and creates an enduring impact. In this paper, we have highlighted the critical need for targeted institutional postharvest capacity building, the need for donor investment to be more responsive of local conditions, the importance of first understanding the operations and dynamics of fruit value chains before seeking to improve them, that little is going to be achieved in the absence of a more holistic approach to horticultural productivity, and emerging opportunities to assist outer-island fruit value chains.

REFERENCES

- AAACP (2009a) Fruit and vegetables sector strategy for Samoa. Retrieved from http://www.intracen.org/uploadedFiles/intracenorg/Content/Exporters/Sectoral_Information/Agricultural_Products/Fruits_and_Vegetables/Samoa%20Strategy%20launch%20final%20aug.pdf
- AAACP (2009b) A sector development strategy for the fruits & vegetables and roots & tubers industry in Fiji. Retrieved from <https://www.yumpu.com/en/document/view/41902129/fiji-sector-strategy-for-fruits-amp-vegetables-and-roots-amp-tubers-aaacp>
- Arpaia, M. L. (1994). Preharvest factors influencing postharvest quality of tropical and subtropical fruit. *HortScience*, 29 (9), 982-985.
- Berno, T. (2011). Sustainability on a plate: Linking agriculture and food in the Fiji Islands tourism industry. *Tourism and Agriculture: New Geographies of Consumption, Production and Rural Restructuring*, 87-103.
- Chung, J. (1987). Fiji, land of tropical cyclones and hurricanes: A case study of agricultural rehabilitation. *Disasters*, 11(1), 40-48.
- Cocker, E. (2000). Postharvest handling status and problems of the Pacific Island countries. In G.I. Johnson, Le Van To, Nguyen Duy Duc & M.C. Webb (Eds.) *Quality assurance in agricultural produce*, (pp. 57-59). Canberra, ACIAR Proceedings 100.
- Duncan, R. & Sing, Y. W. (2009). The failure of agricultural policymaking in Fiji. *Pacific Economic Bulletin*, 24(2), 168-184.
- Eti-Tofinga, B., Douglas, H., & Singh, G. (2017). Influence of evolving culture on leadership: a study of Fijian cooperatives. *European Business Review*, (in press).
- FAO. (2017). Global action programme on food security and nutrition in small island developing states, Rome, pp. 73.
- Hazelman, M., & Pilon, B. (1997). The Importance of Fresh Fruit and Vegetables in the Pacific Region. In *ACIAR Proceedings* (pp. 15-18).
- Hofman, P. J., Smith, L. G., Meiburg, G. F., & Giles, J. E. (1997). Production locality affects mango fruit quality. *Australian Journal of Experimental Agriculture*, 37(7), 801-808.
- Kumar, S. (2017). Postharvest handling practices and losses of tomato along value chains in Fiji. (Doctoral dissertation). *University of the South Pacific*, Fiji.
- Morgan, E. H. (2014). *Value chains for nutrition: the applicability of value chain approaches to address low fruit and vegetable consumption in Fiji (Doctoral dissertation)*. London School of Hygiene & Tropical Medicine, UK.
- Nath, P. (2014). Horticulture Potential in Fiji Island. *Progressive Horticulture*, 46(2), 175-183.
- Rehman, A., Malik, A. U., Ali, H., Alam, M. W., & Sarfraz, B. (2015). Preharvest factors influencing the postharvest disease development and fruit quality of mango. *Journal of Environmental and Agricultural Sciences*, 3, 42-47.
- Rolle, R. S. (2006). Improving postharvest management and marketing in the Asia-Pacific region: issues and challenges. *Postharvest management of fruit and vegetables in the Asia-*

-
- Pacific region*, 23-31.
- Sams, C. E. (1999). Preharvest factors affecting postharvest texture. *Postharvest Biology and Technology*, 15(3), 249-254.
- Sole, D., Henriod, R., Diczbalis, Y., Stice, K. N., & Tora, L. (2014). Modified atmosphere packaging effects on the postharvest quality of papaya fruit. In *XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes* (IHC2014): IV 1111, (pp. 119-124).
- Solomon Islands Ministry of Agriculture and Livestock. (2015). *Solomon Islands agriculture and livestock sector policy 2015–2019*. Retrieved from https://pafpnet.spc.int/images/articles/policy-bank/solomon/Solomons-Islands-NALSP_Final%20Draft_151118.pdf
- Stice, K. N., McGregor, A. M., & Kumar, S. N. (2007). A review of fresh breadfruit exports from Fiji." In *I International Symposium on Breadfruit Research and Development*, 757, 243-249.
- Stice, K. N., McGregor, A. M., Kumar, S. N., & Konam, J. (2010). Fiji Red papaya: progress and prospects in developing a major agriculture diversification industry." *Acta Horticulturae*, 851, 45-52.
- Taylor, M. B. & Tuia, V. S. (2007). Breadfruit in the Pacific region. In *International Symposium on Breadfruit Research and Development*, 757, 43-50.
- Underhill, S. J. & Kumar, S. (2014). Quantifying horticulture postharvest wastage in three municipal fruit and vegetable markets in Fiji. *International Journal of Postharvest Technology and Innovation*, 4(2-4), 251-261.
- Underhill, S.J.R. & Singh-Peterson, L. (2017). Improving non-communicable disease remediation outcomes in Tonga: the importance of domestic fruit production systems: an analysis. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 118(1), 91-103.
- Underhill, S.J.R, Zhou, Y., Sherzad, S., Singh-Peterson, L., & Tagoai, S.M. (2017). Horticultural postharvest loss in municipal fruit and vegetable markets in Samoa. *Food Security*, (in press).
- Underhill, S.J.R. (2013a). Improving the effectiveness of small-holder farm postharvest practices in Fiji. *Acta Horticulturae*, 1011, 41-48.
- Underhill, S.J.R. (2013b). An overview of postharvest research, extension and education capacity in the Pacific with a focus on Western Samoa, Tonga and the Fiji Islands. *Acta Horticulturae*, 1011, 425-432
- Vanuatu Department of Agriculture and Rural Development. (2017). *Vanuatu National Fruit and Vegetable Strategy*. Retrieved from <http://www.nab.vu/sites/default/files/documents/F%20%26%20V%20Strategy.pdf>
- Veit, R. (2009). Assessing the viability of collection centres for fruit and vegetables in Fiji: a value chain approach. *FAO All Acp Agric. Comm. Program. Ser. paper, 7*. Retrieved from http://www.fao.org/fileadmin/templates/est/AAACP/pacific/FAO_AAACP_Paper_Series_No_7_1_.pdf