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Impact of Cyclone PAM on Rainwater Harvesting Prospects in the Pacific Region

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Aims: To assess the impact of cyclone PAM on the rainwater harvesting prospects in the Pacific region.

Study Design: The study was conducted based on the field observations, data from various government organizations and NGOs.

Place and Duration of Study: The study was based in Port Vila, Vanuatu along with nearby Island countries like New Caledonia, Solomon Islands, Fiji and Tuvalu were part of the study. The study was conducted from mid-March to the end of June, 2015.

Methodology: The study was based on the field observations; estimates from authenticated sources with the evidence of the pictorial data of remote areas; community feedbacks; government department's data and NGO's reports. The views of individuals, community heads, government bodies and relief workers of various national and international agencies were integral part of this assessment.

Results: The impact of category 5 cyclone PAM on the prospects of rainwater harvest in the Pacific region was at the highest order. An average of 76% damage to these was recorded in the region.

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Conclusion: A serious introspection had risen for the regional practices of rainwater harvesting in the Pacific and seems in bringing a drastic change for sustainable practices which would withstand the global changes. May be an integrated model with traditional setup and modern equipment shall make sure for sustaining future natural disasters besides longevity and for the better prospects.

Keywords: Cyclone PAM; impact assessment; pacific region; rainwater harvesting.

1. INTRODUCTION

Rainwater harvesting for drinking had been an ancient practice for human civilization. According to Pacey and Cullis [1], it is the gathering and storage of water running off surfaces on which rain has directly fallen, could be a potential alternative in small communities that cannot be served by more centralized water supply schemes. Meanwhile United Nations [2] observed that the climate-change has been impacting on the water resources are especially troublesome for small island developing states. It is obvious of the observation refereeing to the Pacific region where the natural calamities having huge impacts. Pandey et al. correlated between heightened historical human efforts for construction of rainwater harvesting structures across regions in response to abrupt climatic fluctuations [3]. They further added that historical societal adaptations to climate fluctuations may provide insights on potential responses of modern societies to future environmental changes that have a bearing on water resources, food production and the management of the natural systems. Waller [4] reported that rainwater harvesting would be the best alternative source for drinking water in the developing and developed countries and Radhakrishna concluded it as a time-honored practice since ages [5].

According to Hunt's studies in Kiribati and Tuvalu countries of the Pacific region, the lack of management skills and poverty are making them to stick to the traditional methods in the rainwater harvesting [6]. On contrary Barron and Jessica reported that the technologies that can be of in-situ and ex-situ techniques to collect and store water depend on the cultural and developmental issues [7]. The same was being reported by Moglia et al. [8] as, the complexity in water supply methodologies and to be acquainted has been preventing many communities in the Pacific region to favor the traditional methods. He further felt that the political uncertainty in these communities as well as at the national level was a major factor in bringing up any change in their livelihood. The under development might be an

issue but the cultural dominance had not only been confined to rainwater harvesting but in all aspects of pertaining to the life style in the Pacific region. May be time and need shall decide the fate of the systems, but already scarcity for the growing population has been evident in most of the regions of the Pacific. White et al., felt that there were many limitations in the use and storage of harvested rainwater in Kiribati of the Pacific region [9], which reflects the status of the rainwater harvesting practices in the region.

But in the Pacific region, rainwater harvesting is considered as a mandatory set up in the civil planning and has been accepted widely at both public and private places. The same was being reported by Kim [10] in some places around the world. Stockholm Environment Institute (SEI) [11] refers the practice as a blessing from the sky whereas, according to Conserve Energy Future (CEF) was keen in reporting its disadvantages as well [12]. Radha and Bharat [13] had earlier observed the positive impact of rainwater harvesting on the society, economy and ecology but, the recent impact due to the cyclone PAM had left prospects to decline in all ways in the Pacific region. Being mostly dependent on the monsoon for the water resources, the Island nations had been practicing the harvest culture as their reliable and main source of water. In view of the above, an impact assessment was conducted with focus on the extent and the contributing factors of the damage to rainwater harvesting. The cultural practices along with modernized review in the harvesting besides a note on the challenges in the region were also considered in the evaluation. The role of the government and challenges for sustainable practices were also briefly discussed in the assessment.

1.1 Rainwater Harvesting in the Pacific Region

Being a monsoon dominant region, the Pacific had been in its culture to have the rainwater to be harvested mainly for the drinking purpose. It is almost mandatory during any construction to have the system to be a part of the design. May it

be a community one or of an individual, it has been the tradition with pride to be a part of one's life style. It had been based on the strong cultural impact with a belief of being with the nature. People in the Pacific consider drinking the rainwater is more pious than any other form of water as they consider it the other form of God. It was being the same reported by Mosley of the South Pacific Geoscience Commission in his report as, in almost all Pacific Island countries properly collected and stored rainwater is likely to be superior to untreated surface and bore water supplies but this may not always be the case [14]. Obviously the extent of monsoon might be the reason in the Pacific region that makes the natural resource to their footsteps but the economic status establishes the fact of the modernization for supplied water is far behind the reality. But, now-a-days the government has been firm in implementing sustainable practices in protecting the natural resource in the region and is obviously of the pressure from the funding countries for varied benefits in their investments.

May be the systems might be changed with the generations but the practice remains still the same and shall remain so as a part of their rich cultural inheritance. It was observed that children in the Pacific are being told the stories of the harvesting and its advantages rather being just left to see and inculcate the tradition. Angrill et al. [15] observed the same and reported that the cultural practices sometimes are the most environmentally friendly strategy in rainwater harvesting. It was prevailing here that being a part from the cave culture to collect the water from outside, people used ditches on the ground on the plains. The reason harvested water being given importance over the agriculture than for drinking is the constant monsoon and shortage for freshwater resources in these areas. Now being a part of the modernization, cement and plastic tanks with perfect roof channeling were being implemented for the most output. The increased harvesting culture here had a reason of the increased development of the intrusion zones by which salinity has been a problem and it's obvious with being the Islands. It was also due to the development and disappearance of the lagoons with seasonal fluctuations by the climate changes taking place in the Pacific region.

The peculiarity of the rainwater harvesting systems incorporation here are the open collection types as the collected water can be accessed by anyone. Generally this is seen at community based collective systems but people

here are more open for those who are thirst enough to collect and drink. The design shall have the system being placed in such a way that it is accessible in a public way rather than considering it to be a private property. This had been a drawback as the collecting channels run too long from the roofs. The supporting structures with coconut strings or hangers with crawler stems often make them susceptible to develop cracks due to gravity at various points. The intensity and flush rate of the rainwater also affect the channel joints in these cases. In general, the individual systems shall be of plastic tanks of varied sizes depending upon the economic status whereas the communities based are of concrete. These too vary in their length and breadth based on the size of the community or in some cases based the type of aid. Many international agencies primarily focused on the construction of these systems as a part of their charity and the dominant contributors are from Australia and New Zealand. Recently China is being actively participating in these types of activities in the region.

The damage to the harvested systems by the natural calamities and the recovery are part of the Pacific life style. There were instances of past like cyclone UMA in 1987 and a major earth quake in 1992 where, irreparable damage was done not only to the rainwater harvesting systems but to the people as well. Every time there was an awareness to meet the calamities and to strengthen the constructions, poverty was one of the reasons on their way all the time between the thoughts and actions. The cultural dominance over the modernization has been a major factor to consider, as most of the communities still believe that cultural heritage shall recon since ages for their prosperous lives in the region. May be this would be a factor for most the people still depend on harvested water rather to use the supplied water by paying. Even the general thumb rules of cleaning water by cloth filtering or boiling were not being the part here before the consumption. There is still no momentum in the spread of the awareness for clean drinking water and hope there would be soon enough. Lye [16], Morrow et al. [17] and Kwaadsteniet et al. [18] reported the health implications of direct drinking from the roof collectors but, belief from cultural heritage had been making the scientific reasoning no value. On the contrary, Jones and Hunt reported that there was recent interest in the southern parts of America in having rainwater harvesting systems for domestic and agricultural use [19].

2. METHODOLOGY

The study was aimed to assess the extent of damage to the traditional rainwater harvesting systems by the cyclone and thus the impact assessment was studied. The base of the study was at the capital of Vanuatu, Port Vila and extended to the other Islands. Reports from the nearby Island countries like New Caledonia, Solomon Islands, Fiji and Tuvalu were considered in the evaluation of the impact (Fig. 1). The estimate was authenticated from sources with the evidence of the pictorial data as these include the reports from the remote areas without any communication facilities. The study was effective as it was done the next day from the impact and could gauge the damage as it stands. The views of individuals, community heads, government bodies and relief workers of various national and international agencies were integral part of this assessment.

The earlier stages of the impact assessment were very difficult due to lack of transport facilities, flooding, curfew, reluctance to give feedback from some communities and so on.

Care was taken in eliminating the harvesting systems which were already in damaged condition or which were being not used for some time and most of these include the community harvested systems. The onsite review in most of the Islands of Vanuatu gave sufficient information in the assessment and the extent of the damage was audited. These included the Islands of Tanna, Malekula, Espiritu Santo, Ambae and Pentecost.

3. RESULTS AND DISCUSSION

The cyclone PAM was a category 5 type and was considered a monstrous one that left most of the Pacific region countries devastated. It started at latitude of -8.5 and longitude of 169.8 and crossed the bay at -33 and 178.3 in the Pacific region (Fig. 1). With whirlpool winds over 250 Km/h uprooted gigantic trees and seen them flown like cotton fibers. Port Vila, the capital of Vanuatu being in the eye of the cyclone had the destruction at its highest order (Fig. 2). Being pith dark and unbearable whistles of the wind squirrels with heavy rain, it was a nightmare. The inner vision from the sounds of the flying

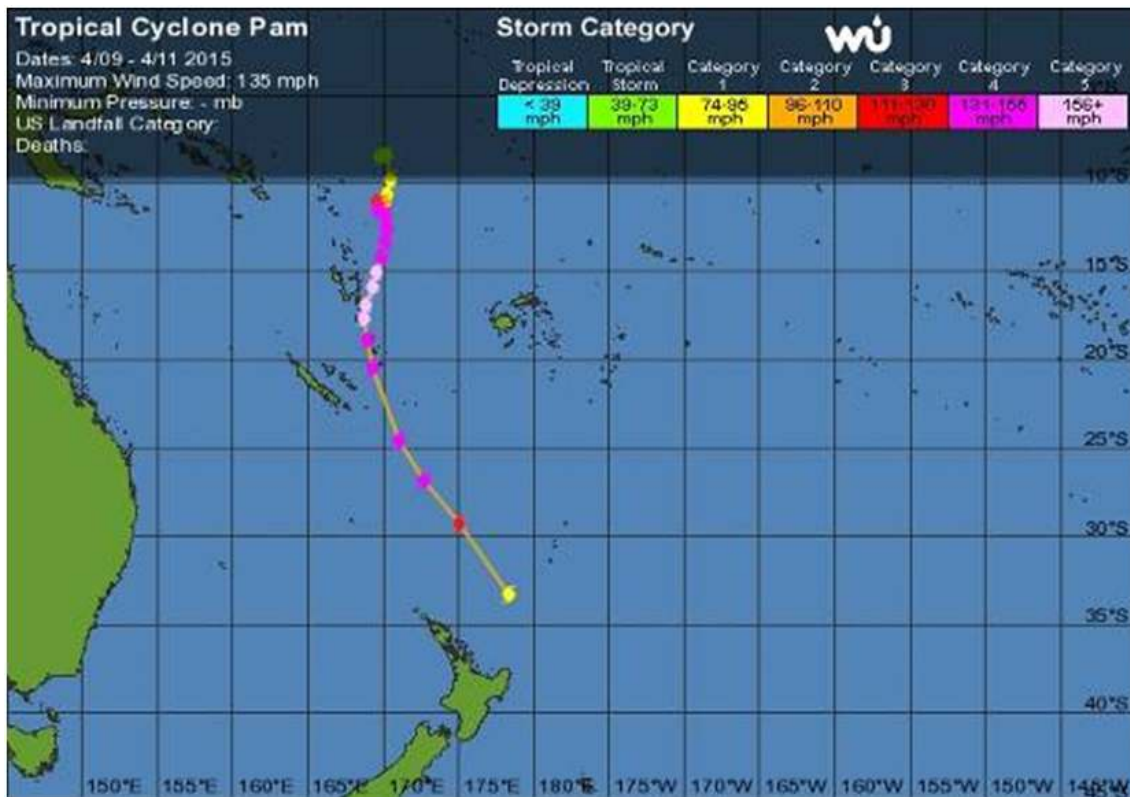


Fig. 1. Satellite image of the Pacific region cyclone pam

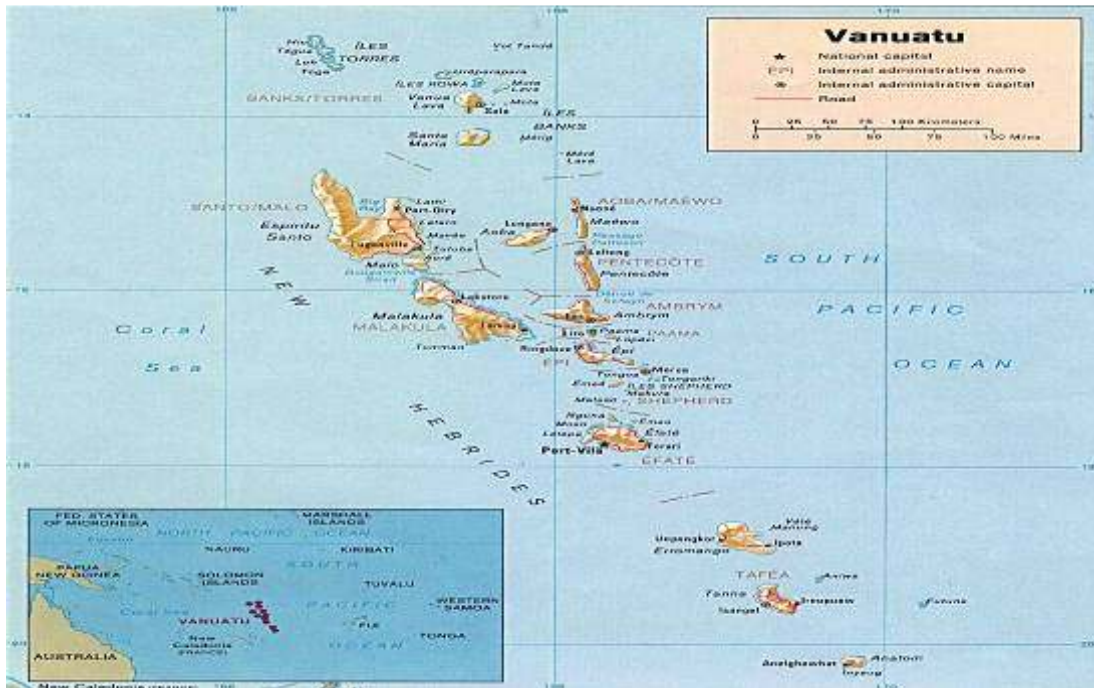


Fig. 2. Map of Vanuatu and other Island countries

roofs and collapses thought that one should never get off from their position and shall remain where they are. It would be nothing sort of a hell for the children along the shores who were to be covered under the fiber boats all night. It was a night where a single thought of 'survival' being prevailed all over the Pacific region. The Asian Development Bank had estimated that more than 50 million dollars of loss and damage occurred to the infrastructure besides personal and human loss. The UNO pronounced it as the loss of an unprecedented extent and would take decades to be refilled for the tiny Island nations. The extent can be imagined as in the preliminary reports said that over 70% of the harvest would have to be percolate down to the land or merge into the sea. It was in one way a boost for the groundwater levels but been little use in the Pacific region.

The magnitude of the damage was evident in the daylight as everything was down by the devastation. The survey of the private systems reached to an average of 84% along the coast and 69% in others areas with an overall estimated damage of 76% from the overall reports. The average damage recorded in the villages was around 62%. Tanna Island of Vanuatu recorded a maximum of 92% damage to its rainwater harvesting systems and Suva

capital of Fiji Islands with a least of 11%. In Honiara of Solomon Islands at extent of 57% damage was recorded. In Tuvalu and New Caledonia countries the damage was around 43% and Fiji with the least of 18% were being assessed from the reported data. The damage being varied with the cyclone changing its direction without predictions and speed. This had made most of the preparatory arrangements in vain at most of the places. It was warned to be a category 3 cyclone at the most but, it had crossed the expectations of the Joint Typhoon Warning Center (JTWC) and recorded as 5. It was later announced of the deviation was of the sudden depression developed in the South Pacific Ocean. The misgauge in the warning had some serious impact on many places of the Pacific region and it was understood that the technological update is being seriously thought by the World Bank for the region.

The roofs were seen hanging on the tree tops was a clear report of the gale winds destruction and it was pity that the harvested systems main parts were now being collected from the debris. In the other regions of the Island, the community tanks in Ponga, Ekasup and Erakor villages near Port Vila were severely damaged. Out of the 22 public harvested systems here, 17 were completely ruined and others were damaged to

an extent. The extent of preparatory arrangements made the difference in case to case besides, the approach in construction from the government expertise in some places had saved the day. The harvesting structures were being down by the collapsed coconut trees (Fig. 3) in the Northern parts of the Island. Earlier the same trees were excellent sources of rainwater and protected from mild to strong winds, but they were the culprits this time around. The context coincided with Evans et al. [20] observation that, even though rainwater harvesting is an environmentally sustainable practice but at times the environmental factors do magnify the unwanted natural impacts as well. It was learnt that the change in the direction of the wind in the early hours doomed them. It was recorded that in most of the villages no traces of the systems were observed and especially it was very severe in Mare in the New Caledonia as well as Asau in Tuvalu. The NGO's of Australia were busy in rebuilding the community harvested systems and learnt that they would be ready by the end of the year.

It was evident from the sites that the thin iron roofs and the plastic pipes never gave any resilience at any point and obvious at the power

of the monstrous cyclone. It was a common picture around these countries where many of the houses were left without roof (Fig. 4). Especially areas which were on the hill tops like Erkor mountain suffered the most. Alternative water source from the rivers in absence of harvested rainwater was hampered by the intrusion of salt water from the nearby lagoons. In many places the roofs and channels were seen flowing through the overflowing rivers. The recovery was poor as of the plastic being done to bit and pieces due to the flow rate. Most of the bays were seen heaped with the roofing material, channels and torn plastic tanks of the harvested systems. It was pathetic that neither the collection systems nor the utensils were left, though there was sufficient rain for days after the cyclone. They were forced against their culture to have the bottled water but, they had for the mere survival. In view of these cultural jinxes all over the world Hay and Nobuo felt that, development can be made more sustainable by increasing the ability of systems and societies to adapt to multiple stresses, including climate change [21]. It was reported by Vohland and Barry that rainwater harvesting supported sustainability in the sub-Saharan Africa which has been facing climate change impacts [22].



Fig. 3. A community collection center being damaged by the cyclone PAM



Fig. 4. Roof for the collection of rainwater being blown by the cyclone PAM

It was reported that most of the Islands were flooded by the overflowing local rivers which intensified the damage to the supporting structures of the harvested systems. Being predominant volcanic formations with rich calcium carbonate deposits, the flood water weakened the structures by dissolving the crumbled bases due to the strong winds. Earlier it was a debate in sealing the bases of the rainwater harvesting systems to be sealed with cement base but, in most places the local practice of direct eruptions from the land are preferred. May be the idea would had saved many from the cyclone impact besides protection from the termite attack as well. It was learned that reasons behind the opposition was the thought that the mixing of other ingredients into the land would bring harm and as well spoil the fertility of the nearby areas as well. It seems that the idea had its advantages and concerns but, at the same time need more studies in finding the facts. Even the use of covering for the wooden bases with polyethylene or rubber sheets was not being practiced in many areas as they were against the custom practices. Sometimes the extra support from the cross fixing with other stands has been commendable and a sustainable practice being followed in other parts

of the world but, at the time of instances like present would have no bearing for them at all.

Far away in the North with areas close to the coast and where the cyclone reached first had to face the impact directly and was the place of highest human loss as well. The villages with the harvesting systems were now seems to be past glory and require a mammoth effort in restoration as the transportation for these areas was completely damaged. In most of the villages in Vanuatu and Tuvalu there was damage due to the tangling of the electric wires with the community collection pipes. Most of the pipes were dragged down by the flown wires in all directions and the damage was escalated as they were down to pieces. Iririki Island in Vanuatu being with tourist resorts and a boat bay had been upside down due to the swirls which cut across the small piece of land after hitting the main Island. Here the semi modernized collection tanks and their accessories were seen floating on the seawater. Near Mele bay the community head had called up for the alternatives for immediate water requirements but couldn't succeed as there was conflict among the members regarding the management of the community harvested system. It was understood

that the opposition for the modernization was a minority concern and the community head could go with the majority. In Solomon Islands the impact to the community harvested systems was worth noted as many structures were down with broken plastic tanks.

At the Emalus campus of the University of the South Pacific in Port Vila, the harvesting tanks were torn to pieces being caught in the whirlpool. The largest collection point at the central market in the Lini's highway developed cracks leaking the harvested water. It got away from the sight of the cyclone with its unique structural assimilation in the center of the market beneath the strong wooden roofs backed by concrete basement. It was learned that the government had been soft corned by the cultural influence in the modernization of the public harvesting systems. The help of various organizations from Australia, New Zealand and China in bringing modernization to the harvested systems were welcomed by the government but were mostly denied by the communities. The impact of community meetings with the NGO representatives from the government's side in educating for sustainable practices for withstanding natural calamities has been a positive approach in the region. But the communities were of the strong feeling that their cultural heritage and association with the natural resources might be taken for granted for the western interests. Forster felt that the psyche of the Pacific region communities and people had still to be understood in detail as their cultural diversifications are completely different from others [23].

It was in the expatriate areas of the Islands where the modernized systems with cement tanks and thick iron roofs survived the impact and the damage was estimated to be very low. In Vanuatu it was only around 7% and in Fiji with 2% to the harvested structures. The use of the lengthy and strong nails along the approaches of the channels saved the day for the systems here. Whereas the use of the palm and coconut wood bases with plastic roofing doomed the day for most of the structures in the Pacific region. The integrated solar and harvesting system sets in some of the areas of Malapoa had proved strength of mutual windings and with support of each other in different directions. The same view being reported by Chong et al. [24] that the harvested prospects would be more in having a wind-solar hybrid harvesting systems and would also stand as an environmentally sustainable

practice. It was the same that observed in some villages where tanks backed by tree trunks survived the impact leaving the channels being blown away. It seems that integration with respect other sections of harvesting like downstream, backyards, gardening areas would strengthen and increase the harvest rather than an isolated structures as reported by Wong [25]. The durability of the integrated systems was comparatively higher and on the lighter note at least some remnants shall be there after calamities, proclaims the community head in Tanna Island.

Cowden et al. [26] reported that the integration not only helps in financial obstacles but shall be useful in the long and dry seasons as well. The public and private partnership type of constructions with the government's aid and expertise had made the difference in some areas of the region. The commercial hub of Elluk in Vanuatu and Honiara, Capital of Solomon Islands didn't suffered much as those were made with concrete structures besides the compact shopping complexes. Pachpute et al. [27] observed that the rainwater harvesting practices incorporating integrated approach had increased the productivity of collected water besides durability. It was understood that the political instability at times in the Pacific region had been a major setback in bringing the update in technology. Earlier there were several memorandums of mutual co-operations with countries like Australia, New Zealand, China etc., but soon after the change in the government these seems be lost somewhere. Also the lack of self-economic resources apart from strong tourism resources had always laid severe constrains on the development in the region.

Besides these the strong cultural heritage in the region had always dominated in setting the political agenda with a sole theme of continuing of cultural heritage rather than westernization. It was the same as observed by the father of the nation late Walter Lini but, he had also felt that there would be some good as well in westernization of the Pacific regions [28]. This had been the basic reason that most of the villages still use the feeding from the palm and coconut as the best for the harvested waters and consider the modern parts as perils. The recent encouragement of some of the governments of the Pacific in supplying the harvested equipment with subsidiary prices is a promising step towards the prospects of the future needs. In fact the Prime Minister of Vanuatu was even liberal in

allocation of 20% of the provident fund to be used without any interest and ordered the banks to implement the same as well. But there was severe shortage of the material being observed due to lack of stocks by virtue of sudden huge demand. Again a conflict was raised as some of the communities had opposed imports of the materials and suggested to incorporate traditional usage in protecting the Pacific culture.

It seems that the Pacific region with substantial monsoon would require further strength in countering impacts with integrations from other structures rather than being damaged or with low output. Some of the newly built harvested systems at various schools with the integrated approach and modern equipment had withstood the impact and thus rendering to be the best possible model for these areas. The debate of culture vs modernization had always been a conflict as both had a win-win situation at given times but, it seems that the latter's stake would be more beneficial in these areas. But Mbilinyi et al. [29] reported that indigenous knowledge had been a decision support tool in rainwater harvesting. It seems that the time had come in the region to review and propose a model which would be an integrated of cultural style with modern equipment. As the cyclone had exposed the weak links and strong bases in the existing harvested culture in the Pacific region, the new model should be a blend of these. It would also be taken care of the earlier resilience's before the policy and implementation would be drafted for the region. The open debate and wide consultations with the communities would certainly pave new era in the harvest in the region. Being a region of low communications among various Islands, time would be long enough to bring the consensus of the implementation of a methodology to be adopted by all.

May the introduction of new methodologies like the umbrella model or use of rain barrels etc. in collection of the harvested water should also be a part of the cultural transformation. Earlier in Tuvalu where severe agitation for the community harvested construction was raised by the local communities was later subsidized from the benefits of having long runs of the water availability. The increase in the academic pursuits in the Pacific region has been yielding the fruits for successful negotiations from the educated with the cultural heads in bringing up the modernization. Globalization might be very fast in some places but the Pacific it is a different

place where change would be associated with time and patience. The views of introduction of these in the curriculum in the schools and colleges were thought by some governments but were withdrawn out of political pressures. Fiji which incorporates the Australian curriculum had been making progress in initiating sustainable practices and could reach the people in taking the advantages of the modernization. The introduction of environmental education in some of the French schools in the Pacific region was also commendable in this context. These signs are paving a better way in understanding the nature, the technological way and with the integration of the Pacific culture would yield better prospects for the future.

4. CONCLUSION

The category 5 cyclone, Pam was a nightmare as the trauma continues for those who witnessed and shall render in only way, 'survived' but don't know how. The damage to their cultural rainwater harvesting systems was at the highest order as the gale winds had blown away everything. There were some remnants in the expatriate areas to identify as they belong to the rainwater harvesting but no traces were left in the villages. The extent of damage was significant of the fact that the systems here were being built of casual strength as if they were being temporary. The stands of palm and coconut with plastic for the roofs and channels were ecofriendly but are too weak to sustain any impacts. They might be based on the idea for being the best models to counter earth quakes in the region but, these harvesting systems are vulnerable on all other instances. It was obvious that the intensity would vanish anything but modernization might have reduced the impact but it was against to the Pacific culture. The blessing in the disguise was that the cyclone had raised the debate for sustainable practice in the Pacific region. The conflict of tradition vs modernization of these systems lays here until really something must change. Nevertheless, the encouragement from the governments in the Pacific region for sustainable practices is a promising step in seeing the prospects of harvested systems would sustain future global changes.

CONSENT

The author declares that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Pacey A, Cullis A. Rainwater harvesting: the collection of rainfall and runoff in rural areas. Intermediate Technology Publications; 1986. ISBN: [0-946688-22-7](#)
2. United Nations Framework Convention on Climate Change (UNFCCC). Climate Change: Small Island Developing States. Bonn: UNFCCC; 2005. Available:http://unfccc.int/resource/docs/publications/cc_sids.pdf (Accessed on June 10, 2015)
3. Pandey DN, Gupta AK, Anderson DM. Rainwater harvesting as an adaptation to climate change. *Current Science*. 2003;85(1):46-59.
4. Waller DH. Rain water—an alternative source in developing and developed countries. *Water International*. 1989; 14(1):27-36.
5. Radhakrishna BP. Rain water harvesting. *J. Geological Society of India*. 1997; 50:247-254.
6. Hunt Colin. Property rights and environmental management on Pacific atolls. *Int. J. Social Economics*. 1996; 23(4/5/6):221-234.
7. Barron J, Jessica CS. Rainwater harvesting: A lifeline for human well-being. UNEP/ Earthprint Publication; 2009.
8. Moglia M, Pascal P, Stewart B. Water troubles in a Pacific atoll town. *Water Policy*. 2008;10(6):613-637.
9. White I, Tony F, Taboia M, Mourongo K, Tererei Abete-Reema, Marc O, Pascal P, Anne D. Safe water for people in low, small island Pacific nations: The rural–urban dilemma. *Development*. 2008;51(2):282-287.
10. Kim RH. Rainwater utilization and functional changes in building roof. *Construction Technol. Rev.* 2000;220:13-19.
11. SEI; 2009. Available:<http://www.sei-international.org/news-archive/1537-blessing-from-the-sky-rainwater-harvesting-can-enhance-ecosystem-productivity-and-livelihoods> (Accessed on June 15, 2015)
12. CEF; 2009. Available:http://www.conserve-energy-future.com/Advantages_Disadvantages
13. Radha Goyal R, Bharat Bhushan. Rainwater harvesting: Impact on Society, Economy & Ecology; 2008. Available:<http://www.eng.warwick.ac.uk/ircsa/pdf/12th/2/Goyal-Radha.pdf> (Accessed on June 15, 2015)
14. Mosley Luke. Water quality of rainwater harvesting systems. South Pacific Applied Geoscience Commission, Pacificwater Publication. 2005;3.
15. Angrill S, Farreny R, Gasol CM, Gabarrell X, Viñolas B, Josa A, Rieradevall J. Environmental analysis of rainwater harvesting infrastructures in diffuse and compact urban models of Mediterranean climate. *The International Journal of Life Cycle Assessment*. 2012;17(1):25-42.
16. Lye Dennis J. Health risks associated with consumption of untreated water from household roof catchment systems. *J. American Water Resources Association*. 2002;38(5):1301-1306.
17. Morrow AC, Dunstan RH, Coombes PJ. Elemental composition at different points of the rainwater harvesting system. *Science of the total environment*. 2010; 408(20):4542-4548.
18. Kwaadsteniet De M, Dobrowsky PH, Van Deventer A, Khan W, Cloete TE. Domestic rainwater harvesting: Microbial and chemical water quality and point-of-use treatment systems. *Water, Air & Soil Pollution*. 2013;224(7):1-19.
19. Jones MP, Hunt WF. Performance of rainwater harvesting systems in the South-Eastern United States. *Resources, Conservation and Recycling*. 2010;54(10): 623-629.
20. Evans CA, Coombes PJ, Dunstan RH. Wind, rain and bacteria: The effect of weather on the microbial composition of roof-harvested rainwater. *Water Research*. 2006;40(1):37-44.

21. Hay John, Nobuo M. Supporting climate change vulnerability and adaptation assessments in the Asia-Pacific region: An example of sustainability science. *Sustainability Science*. 2006;1(1):23-35.
22. Vohland K, Boubacar B. A review of in situ rainwater harvesting (RWH) practices modifying landscape functions in African drylands. *Agriculture, Ecosystems & Environment*. 2009;131(3):119-127.
23. Forster P. Psychology in Vanuatu. *Psychologist*. 2005;18(5):288-289.
24. Chong WT, Naghavi MS, Poh SC, Mahlia TMI, Pan KC. Techno-economic analysis of a wind-solar hybrid renewable energy system with rainwater collection feature for urban high-rise application. *Applied Energy*. 2011;88(11):4067-4077.
25. Wong Tony HF. An Overview of water sensitive Urban design practices in Australia. *Water Practice & Tech*. 2006;1(01).
26. Cowden Joshua R, David Watkins W, James Mihelcic R. Stochastic rainfall modeling in West Africa: Parsimonious approaches for domestic rainwater harvesting assessment. *J. Hydrology*. 2008;361(1):64-77.
27. Pachpute JS, Tumbo SD, Sally H, Mul ML. Sustainability of rainwater harvesting systems in rural catchment of Sub-Saharan Africa. *Water Resources Management*. 2009;23(13):2815-2839.
28. Lini W. Beyond pandemonium: From the New Hebrides to Vanuatu, Asia Pacific Books; 1980.
29. Mbilinyi BP, Tumbo SD, Mahoo HF, Senkondo EM, Hatibu N. Indigenous knowledge as decision support tool in rainwater harvesting. *Physics and Chemistry of the Earth, Parts A/B/C*. 2005; 30(11):792-798.

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