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# EFFECTIVENESS OF AQUAPONIC AND HYDROPONIC GARDENING TO TRADITIONAL GARDENING

**Ezekiel Okemwa 1**

1 Technical University of Mombasa (TUM),
Faculty of Applied Science,
Department of Environment & Health Sciences
Tom Mboya Avenue
P.O. Box 90420-80100,
Mombasa, Kenya

1 National Commission for Science, Technology and Innovation (NACOSTI),

P. O. Box Number 30623-00100 Nairobi, Kenya.

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**Abstract**

*Aquaponics is the integration of aquaculture and hydroponics. There is expanding interest in aquaponics as a form of aquaculture that can be used to produce food closer to urban centers. Commercial aquaponics uses methods and equipment from both the hydroponics and aquaculture industries. There have been few studies of commercial-scale aquaponics production.*
*Traditional farming contributes to household food security by providing direct access to food that can be harvested, prepared and fed to family members, often on a daily basis.*
*Even very poor, landless or near landless people practise gardening on small patches of homestead land, vacant lots, roadsides or edges of a field, or in containers. Traditional farming may be done with virtually no economic resources, using locally available planting materials, green manures, "live" fencing and indigenous methods of pest control. Our survey findings provide a better understanding of the business of aquaponics, which may enhance future commercial operations.*

**Keywords:** Aquaponic, hydroponics, traditional gardening, soil based, soil-less, urban farming; water scarcity, land problem, fish, plants, vegetables

## INTRODUCTION

The paper is based on a thorough review of the scientific literature on aquaponics, hydroponics and traditional gardening, discussions with specialist aquaponics researchers and producers; analysis of web resources; an online survey of aquaponics initiatives and traditional gardening; and visits to operating aquaponics initiatives.

By 2050 world population is projected to increase to 9 Billion and by the same time it has been estimated that as much as 50% of the world's arable land may be unusable. In order to feed this burgeoning population food production will have to increase by 110%. Clearly this is not possible without a radical rethink of production techniques and dietary needs. The western diet needs to change away from its dependency on high protein meat sources and over consumption. The West has to address our wanton wastage of food where we are currently throwing away 30% of the food we buy. Governments will also have to address the thorny subject of land tenure. China and the Gulf States are already looking at purchasing land in other countries in order to feed their own populations. It may well be time for us all to look at the consequences of nationalising productive land in order to ensure an equitable distribution of food, Griffith, P. et al., 2015.

### Unnatural roots of the food crisis

Feeding the world requires healthy ecosystems and equitable governance.
The current model of market-driven food production is leaving people hungry.
It has turned food into a commodity subject to all the market failures that create inequities and negative impacts on the environment. There is a global food crisis. A myriad of events are convening the international community to reflect on the urgent situation. Just in the past month, the UN Commission on Sustainable

Development and the UN Convention on Biological Diversity focused considerable attention on agriculture and food security.

But this crisis has been long coming. Unsustainable agricultural policies and technologies, inequitable trade rules, agricultural subsidies that distort the markets, and the systematic marginalisation of small producers lie at the heart of the problem.
In addition, there is chronic under-investment in agriculture in developing countries, and a real neglect of the basic premise that ecosystems have to be in good shape in order to provide good food.

**Costs of production**
The past 50 years have seen massive expansion of agriculture, with food production more than doubling in order to meet demand.

But it has left us with 60% of all ecosystem services degraded, accelerated species extinction, and huge loss in genetic diversity. Neglecting ecosystems concerns has provoked a fisheries crisis too. Currently, four plant species - wheat, maize, rice and potato - provide more than half of the plant-based calories in the human diet, while about a dozen animal species provide 90% of animal protein consumed globally. We have already lost three-quarters of the genetic diversity of agricultural crops.
As the agricultural frontier has expanded, those farmers previously dependant on a more diverse source of livelihood have converted to cash crops.

As traditional varieties and breeds die out, so too do the traditional knowledge and practices of local farmers. Those same practices could now be critical in adapting to climate change.

The focus on agricultural commodities rather than on food production to meet the basic needs of people has undermined diversity and self-reliance, and left farmers vulnerable to volatile markets, political instability and environmental change. Increased food production in some parts of the world has been at the expense of natural and semi-natural ecosystems that provide us greater long-term security. Amazingly, there is very little attention being paid to what fundamentally underpins all of our food systems – biodiversity and the services provided by ecosystems.
In Britain, studies have shown that hay production is higher in meadows with a greater number of species. In Australia, crop yields are higher in regions where native biodiversity has been preserved. In the seas, too, areas with a higher number of conserved species generate more fish for humans to catch and eat.
There are many other examples from land and sea to show that a healthy environment means more food and a greater capacity to survive natural disasters.
The current food crisis, meanwhile, will only be exacerbated by climate change, with southern Africa and South Asia expected to be particularly badly affected.

**Market transformation**

So what are the solutions to feeding a growing world population in the face of climate change? There is information about a Green Revolution for Africa, major irrigation and fertilisation programmes, genetically modified seed varieties, as well as banning the use of crops for biofuel production.

Amazingly, there is very little attention being paid to what fundamentally underpins all of our food systems - biodiversity and the services provided by ecosystems, such as soil, water and resilience to disasters.

There is need to attack market failures and change the economic rules of current food production systems.

There is need to eliminate agricultural and fisheries subsidies that support elites in the North, and get rid of protectionist measures in OECD countries for agricultural products.

There is urgent need to allow for value-added trade for the benefit of the South, and expand fair trade and labelling processes that create incentives and add benefits to producers in the South.

We must change food production systems, moving from the existing model based on high inputs (such as fertilisers) accessible through markets, to systems based on locally available and more environmentally-friendly inputs. Developments such as aquaponics and hydroponics can reduce farmer's use of resources.

There is need to create alternative trade rules and circuits that reduce the payout to middlemen and big agribusinesses.

There must be greater investment, including by bilateral and multilateral development co-operation, to support food production systems that feed the poor and supply local markets.

The governance model related to natural resources has to change. There is need to expand small farmers' and landless peasants' access to productive assets in countries of the South - lands, water sources and fisheries.

There needs to be a shift away from the prevailing model of concentration of land in small groups of big landowners who are dropping food production for local markets and moving to big industrial production of commodities that produce no local benefits, Gonzalo Oviedo, 2015.

**Differences between Aquaponics and Traditional Foods**

The differences between aquaponics, hydroponics and traditional foods stem directly from the farming methods that were used during the food's production. Many people are unaware of some of the differences between the two practices. Agriculture has a direct effect on our environment, so understanding what goes into our agriculture is important. Below is a diagram showing some of the key differences between soil-based traditional system and recirculating aquaponic system.

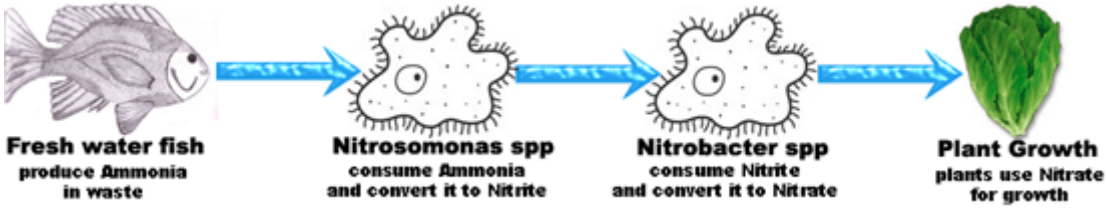
One of the biggest differences that is seen time and time again across all research between the two farming practices is the effect on the land. Aquaponics combines fish farming (aquaculture) with the practice of raising plants in water (hydroponics). It's organic by definition: instead of using chemical fertilizers, plants are fertilized by the fish poo (and pesticides/herbicides can't be introduced to kill pests because they could harm the fish). Since the plants don't need dirt, aquaponics allows gardeners to produce more food in less space. And in addition to the vegetables they can grow, most aquaponics gardeners cultivate edible fish as well.

**Aquaponics Systems the Ideal**

Today, modern aquaponics is a viable resource to sustainability that combines aquaculture (growing fish and p lants in a controlled environment) and hydroponics (growing plants without soil). The system relies on fish w aste to provide organic food and nutrients to help the plants grown; in turn, the plants clean, filter, and recycle the water back to the fish creating a symbiotic relationship (Dunn, 2012).

Aquaponics may be regarded as the integration of two relatively well established production technologies: recirculating aquaculture systems in which fish tank effluent is treated and cleaned before being returned to the fish tank; and hydroponic (or soil-less) nutrient solution based horticulture systems. Bringing the two together allows for the plants to utilize the waste nutrients produced by the fish. In principle it is very similar to a freshwater aquarium in which both plants and fish are grown.

Fish produce ammonia (among other things) as a waste product of respiration and their general metabolic processes. While ultimately deadly to fish, this chemical is a potential boon for plants. All they require to is a little help from naturally occurring and largely omnipresent nitrifying (meaning they convert the ammonia to nitrates) bacteria, which reside in a porous, inert growing medium, inside a plant grow-bed. Nitrifying bacteria convert fish wastes into plant-available nutrients. The plants use these nutrients as their main nutrient supply. The fish benefit from this process also, as the water is filtered by the plants, giving the fish clean water to live in. With Aquaponics, both the fish and the plants not only grow well, they flourish.




*Water from the fish reservoir is pumped into the grow-bed, where the bacteria process the ammonia into a form available to plants, which then take it up and flourish. The water, now 'biologically filtered', is returned to the fish tank, gaining oxygen along the way.*

The ideal of Aquaponics systems came from combination of Aquaculture and Hydroponic systems. It came as the best solve for the negative sides for both Hydroponic and Aquaculture.

**Figure 2: Simple small-scale aquaponic System** (courtesy Cook Islands Aquaponics Pilot Project)

Aquaponic systems come in a wide variety of forms, ranging from a simple fish tank set below a gravel filled vegetable bed (which also serves as a simple biofilter), with water from the fish tank pumped up and through the grow bed; to highly sophisticated systems incorporating multiple fish tanks, solid waste removal systems, aerobic and anaerobic biofilters, intensive aeration systems for both plants and fish, and sophisticated water quality monitoring and backup (i.e. fail-safe) systems.

Aquaponic systems are dominated by vegetable production in terms of area and quantity of product. This is biologically determined by the quantity of plant production required to absorb the waste nutrients generated by fish. In some of the more commercial systems, the fish are simply regarded as a source of high quality organic nutrients, rather than as marketable product in their own right.

The technology of aquaponics has been with us since the 1960's, but interest has increased rapidly in recent years due to widespread interest in local sustainable food initiatives, and awareness amongst development agencies that aquaponics may allow for the production of both vegetables and fish in water-deficient or soil-deficient zones. The technology is also of particular interest to aquaculture scientists as a possible tool for the reduction/remediation of nutrient waste from intensive aquaculture production. Scientists, educators and community or development NGOs are, furthermore, particularly attracted to a technology that represents a small managed "ecosystem" comprising a highly productive balance of fish, bacteria and plants.

All operations appeared to rely on a niche market and price premium, associated in most cases with a local farm shop, visitor attraction or café outlet. Others were able to sell into more mainstream but high value markets (e.g. in Hawaii) and generate a small "sustainability" or organic premium.

**Table 2: Types of aquaponic enterprise**

| Type | Key characteristics | Funding/profitability/motivation |
|---|---|---|
| Kitchen window | Very small scale household systems suitable for growing a few herbs and salad | Convenience/quality of life/interest rather than profitable |
| Backyard/smallholder | Small scale enthusiasts system similar to owning a greenhouse for home vegetable production | Primarily a hobby activity but yielding significant production for home consumption and sharing with neighbours. |
| Research/demonstration | Small-medium and medium large systems designed for research and demonstration purposes | Primarily research funding; may sell some produce to contribute towards running costs; excellent education/training tool |
| Community initiative | Varied in character but typically medium scale enterprise built using public funds and operated by local community NGOs. Often combined with waste recycling initiatives, work placements, and/or organic and local food initiatives | Usually public investment from local, national, regional and international social and economic development funds |
| Sustainable food outlet | More commercial and entrepreneurial | Funding for the aquaponic system is either cross subsidy from the food outlet, or enhanced margins related to sustainability image |
| Sustainable research, training, supplies and consultancy services | Selling "sustainability" – ideas, products, services, training, research | Primarily from sales of equipment and services rather than from fish/vegetables |
| Organic hydroponics | Primarily a hydroponics vegetable production system using fish a source of organic fertilizer and sustainability image booster | Primarily from sales of vegetables in premium gourmet, organic and local markets |
| Organic re-circulating aquaculture | Primarily intensive fish production in recirculation system with fertilization of vegetables as secondary waste treatment | Intensive aquaculture has a mixed reputation with regard to input use and waste generation, and this is an attempt to minimise waste from intensive production systems while at the same time benefitting from organic or sustainability credentials/image |
| Smallholder integrated fish agriculture systems | Fish grown in ponds; vegetables grown in ponds; pond sludge used to fertilize plants | Primarily subsistence systems, still common in S and SE Asia, but generally in decline and being replaced by more specialist intensive systems |

## Global experience

Aquaponics initiatives can be found throughout the world, from deserts to northern cities to tropical islands. The industry is dominated by technology and training suppliers, consultants, "backyard" systems and community/organic/local food initiatives. There are very few well established commercial systems (i.e. competing profitably in the open market) and most of those that are have been cross-subsidized by other economic activities, at least in the start-up phase. Many initiatives in temperate zones appear to be struggling. High capital, energy and labour costs on the one hand, and lack of flexibility in meeting market demand on the other, along with constraints on pest management, have been the major problems to date.

It is notable that those that are commercial or near commercial are located primarily in Hawaii - because it has a relatively stable temperature regime; a long history of demonstration and research; significant constraints on more conventional forms of horticulture; high food import costs; and significant demand for "sustainable", organic and other niche food products.

**Could aquaponics be used by farmers in developing countries?**

"Aquaponics has huge potential to be used by developing countries - both as commercial ventures and a way to provide food," Leslie Ter Morshuizen, owner and founder of Aquaculture Innovations.

Aquaculture advocates also say it is sustainable and eco-friendly. "Water is a precious commodity in developing nations, and because the majority of the water used is recycled through the aquaponics system, significantly less water is consumed than in traditional farming," explains Tony Abuta, founder of Amsha Africa Foundation.

According to Ken Konschel, project founder of Aquaponics Africa, the possibilities are limitless. "Fish grow their own food, so the system is self-supporting. It could improve people in developing countries' lives by increasing food security, employment opportunities and economic growth."

As nutrition is a key issue for developing nations, who rely mainly on staple crops such as wheat and rice, the fish farmed could also provide a valuable source of protein. Abuta adds: "By building Aquaponic systems in developing nations like those in Africa, there would be more food for the population, and it would be more nourishing."

**Strengths/advantages of aquaponics**

Efficiency of water use. Aquaponic systems use 10% or less of the water used in conventional soil based horticulture systems. Water use efficiency in hydroponic systems is probably comparable to that of aquaponics, but more variable, depending on the frequency with which nutrient solution is discarded or dumped.

**Independence from soil.** These systems can be established in urban or harsh rural environments where land is very limited or of very poor quality. This advantage applies also to hydroponics and recirculating aquaculture systems.

High levels of nutrient utilization. This is the core rationale for aquaponics and a significant advantage in those countries or locations where nutrient enrichment 1 is a problem (as for example in some Pacific lagoons). The fish and plants in most aquaponic systems capture roughly 70% of the nutrients input in the form of fish feed; and the residual solid waste is relatively easy to manage and may be applied to fruit trees or conventional horticultural crops.

Although hydroponic systems also capture a high proportion of nutrients most operators dump the system water periodically to prevent the accumulation of salts and pathogens and allow for thorough cleaning and sterilization. In most cases this relatively dilute waste will not be a problem, and may be used for conventional crop irrigation; on a large scale in sensitive locations treatment may be required in an open pond or lagoon. The requirement or otherwise for this will depend on local conditions and regulations.

A further possible advantage lies in the complex organic nature of the aquaponic nutrient solution compared with the relatively simple chemical based solutions used in hydroponics. There is some evidence that this has pro-biotic properties, promoting nutrient uptake and protecting against some disease. There is also some limited evidence of improved product flavour and extended shelf life. Higher levels of anti-oxidants have been observed in aquaponically grown plants. Not surprisingly these benefits will depend on the quality of the nutrients entering the system – and it has been shown for example that higher concentrations of anti-oxidants are related to the quality of the fish food.

**Reduced labour & improved working conditions**. Labour inputs to conventional horticulture are hugely varied dependent on the degree of mechanisation and chemical usage. Aquaponic and hydroponic systems usually use raised beds and do not need weeding. Some of those involved say that there is less work, and the work involved is of a higher quality than that required in more conventional systems. The lack of well established specialist commercial aquaponics enterprises makes comparison difficult.

**Two for the price of one.** There is a widespread belief in aquaponic circles that growing fish and vegetables together must save money – you get two products for your investment, labour, and other operating costs. The indications are that this assumption is false. Keeping fish in aquaponic systems adds significantly to both capital and operating costs when compared with a hydroponic system, and some producers have explicitly stated that the fish lose money. The cost is regarded as necessary in order to generate complex dissolved organic nutrients, and produce a product which can be sold at an "organic" premium.

**Weaknesses/disadvantages**

It is unfortunate that the essential and desirable characteristic of aquaponics – closely integrated production of plants and fish to maximise nutrient utilization – also introduces significant disadvantages from both production and marketing perspectives.

**Compounding of risk.** Intensive aquaculture production may be subject to losses or reduced productivity related to water chemistry, temperature, lack of oxygen, and disease. Intensive horticulture (including hydroponics) may also be subject to losses from system failure (water supply), pests and diseases. Integration of intensive horticulture with intensive aquaculture compounds these risks since problems or failure of one component are likely to reduce performance of the other. Some risks may even be increased – biosecurity (exclusion of pathogens) is a key issue for intensive recirculating aquaculture systems and may be compromised by recirculation through a large outdoor vegetable production facility. Furthermore, the range of management responses (such as pest or disease management) for each component is constrained by the sensitivities of the other, and it may take some time to restore the whole system to optimal performance. These

production risks are further compounded by high capital and fixed operating costs. Any break in production will have substantial cost implications.

**Constraints on optimisation and economies of scale.** The drive towards efficiency in conventional food production has resulted in both specialisation and intensification. Specialist farmers or fish farmers are able to bring all their skills and effort to bear on optimisation of their production system for a particular product, and achieve economies of scale in sourcing, production and marketing. While the desirability of this may be questioned on many other levels, there is no doubt that existing economic incentives at both local and global levels continue to strongly favour this trend. Integration in aquaponics not only flies in the face of these incentives, but the intimacy of the integration prevents optimisation of each component. Optimal water chemistry and temperature are slightly different for fish and plants in most cases.

**Constraints on production and marketing.** Commercial producers adjust their rates of production as far as possible to meet market demand for different products, and according to seasonality of demand. Some hydroponic producers in Rarotonga for example reduce or stop their production when the market is seasonally flooded with conventionally grown vegetables. Maintaining (roughly) a fixed ratio of fish to plant production, and the long delays and high costs related to shutting down and restarting an aquaponic system, significantly constrain flexibility to adjust production in line with demand.

**Energy costs.** Most aquaponic systems will require more energy than conventional horticulture or hydroponics systems, primarily related to the oxygen demand of both fish and bacteria, and the corresponding need for intensive aeration as well as pumping.

**Management costs and demands.** Routine maintenance, water quality monitoring and management can be demanding, requiring both skills and dedication. Furthermore, in order to cover the relatively high capital and operating costs, production from these systems must be maximised, requiring high levels of organisation and management in production scheduling, and highly effective sales and marketing.

**Limited range of suitable fish species.** Tilapia is by far the preferred fish for aquaponic systems, especially in the tropics and sub-tropics. This is because it is extremely easy to breed, adapts well to high density, is tolerant of low oxygen concentrations (and therefore less susceptible to temporary power failure of system blockage) and tolerant of high nutrient concentrations. Flesh quality is also generally good. However, it is non-native to the Pacific region, and introductions of such a robust species in some countries (such as Australia) has had negative impact on native fauna. While such impacts are unlikely to be as severe in biodiversity limited small islands, there may be issues in some countries. Dependence on highly tolerant species also restricts market opportunity.

Nutrient utilization efficiency is not specifically recognised in sustainable food certifications such as organic, and the apparent advantage of aquaponics and hydroponics over conventional agriculture in this regard cannot be readily translated into a price premium on the open market. Indeed organic certification of soilless cultivation is still not possible for many organic labels.

Although aquaponics uses nutrients efficiently, any assessment of sustainability must also take into account the source of nutrients. Unfortunately the most successful aquaponic systems (in terms of system performance and product quality) use high quality fish feed as the primary nutrient source, with up to 40% protein and often a high proportion of fish meal. They also focus on plant rather than fish production. The logic of using fish feed as a source of nutrients for vegetable production in the name of sustainability and food security is questionable. A more rational approach from the perspective of global or regional sustainability would be to use nutrient wastes from other intensive food production systems (including agriculture and aquaculture) as inputs to hydroponic systems. Conclusions The overall balance

Recirculating aquaculture systems, hydroponic systems and (integrated) aquaponic systems all share the advantage of reduced water use per unit production, and are therefore of interest for development in water deficient islands in the Pacific.

From a purely commercial, or economic development perspective, in almost all circumstances, the disadvantages of aquaponics would outweigh the advantages. Integrating recirculating aquaculture with hydroponic plant production increases complexity, compounds risk, compromises system optimisation for either product, restricts management responses – especially in relation to pest, disease and water quality - and constrains marketing. Energy use is relatively high because of the need for both aeration and pumping in most systems. System failure may result in a two month restart and rebalancing period during which time high fixed costs must be covered. Given that most aquaponic systems are dominated by plant production this is a heavy price to pay, and would require a substantial “organic” premium to compensate.

From a sustainability perspective there are substantial questions related to use of high quality fish feeds as the nutrient source for systems focused primarily on plant production, and energy use is also relatively high. Solar or wind driven systems would usually be required to make them both economically viable and environmentally sustainable. From a food security perspective, especially in water constrained islands, it would appear that hydroponics and aquaculture undertaken as independent activities according to local market need would normally be more attractive, although it is possible that if both became successful, the advantages of integration might then be explored.

**Plants: hydroponics**

A Deep Water Culture hydroponic system, where plant grow directly into the effluent rich water without a soil medium. Plant can be spaced closer together because the roots do not need to expand outwards to support the weight of the plant.

Plants are grown as in hydroponics systems, with their roots immersed in the nutrient-rich effluent water. This enables them to filter out the ammonia that is toxic to the aquatic animals, or its metabolites. After the water has passed through the hydroponic subsystem, it is cleaned and oxygenated, and can return to the aquaculture vessels. This cycle is continuous. Common aquaponic applications of hydroponic systems include:

- *Recirculating aquaponics*: solid media such as gravel or clay beads, held in a container that is flooded with water from the aquaculture. This type of aquaponics is also known as *closed-loop aquaponics*.
- *Reciprocating aquaponics*: solid media in a container that is alternately flooded and drained utilizing different types of siphon drains. This type of aquaponics is also known as *flood-and-drain aquaponics* or *ebb-and-flow aquaponics*.
- *Deep-water raft aquaponics*: styrofoam rafts floating in a relatively deep aquaculture basin in troughs.
- Other systems use towers that are trickle-fed from the top, nutrient film technique channels, horizontal PVC pipes with holes for the pots, plastic barrels cut in half with gravel or rafts in them. Each approach has its own benefits, (Lennard, et al, 2006).

Most green leaf vegetables grow well in the hydroponic subsystem, although most profitable are varieties of Chinese cabbage, lettuce, basil, roses, tomatoes, okra, cantaloupe and bell peppers. Other species of vegetables that grow well in an aquaponic system include beans, peas, kohlrabi, watercress, taro, radishes, strawberries, melons, onions, turnips, parsnips, sweet potato and herbs. Since plants at different growth stages require different amounts of minerals and nutrients, plant harvesting is staggered with seedlings growing at the same time as mature plants. This ensures stable nutrient content in the water because of continuous symbiotic cleansing of toxins from the water.

**Animals: aquaculture**

Filter water from the hydroponics system drains into a catfish tank for re-circulation. Freshwater fish are the most common aquatic animals raised using aquaponics, although freshwater crayfish and prawns are also sometimes used (Rakocy...et al, 2013). In practice, tilapia are the most popular fish for home and commercial projects that are intended to raise edible fish, although barramundi, silver perch, eel-tailed catfish or tandanus catfish, jade perch and murray, cod are also used (Rakocy...et al, 2013). For temperate climates when there isn't ability or desire to maintain water temperature, bluegill and catfish species are suitable fish species for home systems. Koi and goldfish may also be used, if the fish in the system need not be edible.

**Bacteria**

Nitrification, the aerobic conversion of ammonia into nitrates, is one of the most important functions in an aquaponics system as it reduces the toxicity of the water for fish, and allows the resulting nitrate compounds to be removed by the plants for nourishment (Diver,..et al, 2006). Ammonia is steadily released into the water through the excreta and gills of fish as a product of their metabolism, but must be filtered out of the water since higher concentrations of ammonia (commonly between 0.5 and 1 ppm) can kill fish. Although plants can absorb ammonia from the water to some degree, nitrates are assimilated more easily (Diver,..et al, 2006) thereby efficiently reducing the toxicity of the water for fish (Rakocy.., 2013). Ammonia can be converted into other nitrogenous compounds through healthy populations of:

- *Nitrosomonas*: bacteria that convert ammonia into nitrites, and
- *Nitrobacter*: bacteria that convert nitrites into nitrates.

In an aquaponics system, the bacteria responsible for this process form a biofilm on all solid surfaces throughout the system that are in constant contact with the water. The submerged roots of the vegetables combined have a large surface area where many bacteria can accumulate. Together with the concentrations of ammonia and nitrites in the water, the surface area determines the speed with which nitrification takes place. Care for these bacterial colonies is important as to regulate the full assimilation of ammonia and nitrite. This is why most aquaponics systems include a biofiltering unit, which helps facilitate growth of these microorganisms. Typically, after a system has stabilized ammonia levels range from 0.25 to 2.0 ppm; nitrite levels range from 0.25 to 1 ppm, and nitrate levels range from 2 to 150 ppm. During system startup, spikes may occur in the levels of ammonia (up to 6.0 ppm) and nitrite (up to 15 ppm), with nitrate levels peaking later in the startup phase. Since the nitrification process acidifies the water, non-sodium bases such as potassium hydroxide or calcium hydroxide can be added for neutralizing the water's pH (Rakocy.., 2013) if insufficient quantities are naturally present in the water to provide a buffer against acidification. In addition, selected minerals or nutrients such as iron can be added in addition to the fish waste that serves as the main source of nutrients to plants (Rakocy....et al, 2013).

A good way to deal with solids buildup in aquaponics is the use of worms, which liquefy the solid organic matter so that it can be utilized by the plants and/or other animals in the system.

**Operation**

The five main inputs to the system are water, oxygen, light, feed given to the aquatic animals, and electricity to pump, filter, and oxygenate the water. Spawn or fry may be added to replace grown fish that are taken out from the system to retain a stable system. In terms of outputs, an aquaponics system may continually yield plants such as vegetables grown in hydroponics, and edible aquatic species raised in an aquaculture. Typical build ratios are .5 to 1 square foot of grow space for every 1 U.S. gal (3.8 L) of aquaculture water in the system. 1 U.S. gal (3.8 L) of water can support between .5 lb (0.23 kg) and 1 lb (0.45 kg) of fish stock depending on aeration and filtration (Diver..et al, 2006).

Ten primary guiding principles for creating successful aquaponics systems were issued by Dr. James Rakocy, the director of the aquaponics research team at the University of the Virgin Islands, based on extensive research done as part of the *Agricultural Experiment Station* aquaculture program (Rakocy....et al, 2013).

- Be careful with aggregates
- Oversize pipes
- Use biological pest control
- Ensure adequate biofiltration
- Control pH
- Use a feeding rate ratio for design calculations

- Keep feed input relatively constant
- Supplement with calcium, potassium and iron
- Ensure good aeration
- Remove solids

**Feed source**

As in all aquaculture based systems, stock feed usually consists of fish meal derived from lower-value species. Ongoing depletion of wild fish stocks makes this practice unsustainable. Organic fish feeds may prove to be a viable alternative that relieves this concern. Other alternatives include growing duckweed with an aquaponics system that feeds the same fish grown on the system (Rakocy....et al, 2013). excess worms grown from vermiculture composting, using prepared kitchen scraps (Rakocy....et al, 2013).as well as growing black soldier fly larvae to feed to the fish using composting grub growers,( Rakocy...et al, 2013).

**Water usage**

Aquaponic systems do not typically discharge or exchange water under normal operation, but instead recirculate and reuse water very effectively. The system relies on the relationship between the animals and the plants to maintain a stable aquatic environment that experience a minimum of fluctuation in ambient nutrient and oxygen levels. Water is added only to replace water loss from absorption and transpiration by plants, evaporation into the air from surface water, overflow from the system from rainfall, and removal of biomass such as settled solid wastes from the system. As a result, aquaponics uses approximately 2% of the water that a conventionally irrigated farm requires for the same vegetable production. This allows for aquaponic production of both crops and fish in areas where water or fertile land is scarce. Aquaponic systems can also be used to replicate controlled wetland conditions. Constructed wetlands can be useful for biofiltration and treatment of typical household sewage (Rakocy..et al, 2013).The nutrient-filled overflow water can be accumulated in catchment tanks, and reused to accelerate growth of crops planted in soil, or it may be pumped back into the aquaponic system to top up the water level.

**Energy usage**

Aquaponic installations rely in varying degrees on man-made energy, technological solutions, and environmental control to achieve recirculation and water/ambient temperatures. However, if a system is designed with energy conservation in mind, using alternative energy and a reduced number of pumps by letting the water flow downwards as much as possible, it can be highly energy efficient. While careful design can minimize the risk, aquaponics systems can have multiple 'single points of failure' where problems such as an electrical failure or a pipe blockage can lead to a complete loss of fish stock.

**Traditional Farming**

- Conventional farming makes use of chemicals, synthetics, and other materials to manage weeds and pests
- Conventional farming uses unnatural farming methods
- Conventional farming use of pesticides has garnered attention towards acceptable levels of toxicity, and whether there should actually be an acceptable level
- Pesticides used in conventional farming can be damaging to your health.

There are many other differences between aquaponics and traditional farming, but these seem to be the most spoken of in regards to consumer health. There have been arguments around whether or not traditional farming methods are safe for one's health. This is because of the pesticides and GMO's used in the conventional farming practices. Many people are concerned that those growing practices promote unsafe chemical use, especially because the level of toxicity is said to be under a "safe" level, but what is really safe?

**Aquaponics Vs. Traditional Farming**

Why is aquaponics better than traditional farming?

i. Aquaponics is capable of growing more produce compared to produce grown conventionally in the ground. Vegetables usually grow significantly faster, and at three to four times the density.

ii. Aquaponics eliminates one of the biggest costs in an aquaculture operation that is filtering the water of fish waste accumulations. However when combined with hydroponics, the plants are the sole source of filtration. Therefore eliminating an enormous cost.

iii. Aquaponics not only grows veggies and fruits, it also produces great tasting fish! Any fresh water fish can be used in aquaponics. The fish are raised without hormones or antibiotics and in the comfort of your own home.

iv. Aquaponics is the perfect solution to many world problems and would be ideal for 3rd world countries. It is also a great solution for drought situations or for those who live in a desert climate. An aquaponics system can produce vegetables and fresh fish with little water and solar power.

v. Aquaponics is a sustainable food production system that combines aquaculture, (raising fish, prawns, crayfish, ect in tanks), with
hydroponics (growing plants in water) in a symbiotic environment so that both grow better.

vi. Aquaponics systems are capable of producing an abundance of food in very small and urban spaces. The food produced is completely organic.

vii. Aquaponics is a great sustainable option for food production for the current age and future. An aquaponics system offers the opportunity to produce healthy and local food in an economically and environmentally sustainable fashion.

viii. In an aquaponics system you have the option to use beautiful tilapia or koi fish to suit your vegetarian or vegan lifestyle. Having an aquaponics garden is very therapeutic, relaxing and fun for children. It is also incredibly rewarding to eat food that you have personally grown yourself.

ix. Aquaponics uses only a fraction of the water used in conventional farming and aquaculture, which is why it's the farming of the future.

x. Aquaponics is for everybody!!

**Petroleum Use: Aquaponics vs. Traditional Agriculture**

Because there is no soil to till, there is no longer a need to use tractors and gas-powered farm equipment. Commercial aquaponics operations typically employ either a raft method, where the plants float in water until they are harvested, or media. Neither requires the kind of labor that soil-based farming does.

Since there are no weeds in aquaponics, there is no need to mechanically remove weeds or spray herbicides. Since the plant nutrients and water are both integral to an aquaponics system, there is no need for petroleum-based fertilizers or truck-mounted irrigators. Since aquaponically grown plants are either growing in waist-high grow beds or in rafts floating in water, they are much easier to harvest than soil-grown plants.

**Location, Location, Any Location!**

Aquaponic systems can be set up anywhere you have, or can artificially establish, an appropriate climate for the plants. Poor soil? No problem. Aquaponics is particularly well adapted to providing food to local communities that might not otherwise have fertile land avail¬able for growing.

Since over half of humanity now lives in our cities, it is important that food-growing facilities be established where the people are, rather than trucking food in from distant locations. Currently, most of our produce is shipped hundreds, if not thousands of miles. Imagine how much fuel could be saved if we actually grew our food in our city centers.

**Water Use: Aquaponics vs. Traditional Agriculture**

Modern agricultural methods waste an incredible amount of water. Water is either sprayed or flooded through fields where a huge amount either evaporates into the air on a hot day, or seeps past the plant roots and into the water table, pulling chemical fertilizers, herbicides and pesticides down with it.

Aquaponics, on the other hand, is a closed, recirculating system. The only water that leaves the system is the small amounts taken up by the plants (some of which transpires through the leaves) or that evaporates from the top of the tank. That's it. Aquaponics uses less than a tenth the amount of water a comparable soil-based garden uses.

Aquaponics is even more water thrifty than it's horticultural cousin, hydroponics. Since aquaponics is an organic ecosystem in which the nutrients are balanced naturally, there is never any toxic build-up of nutrients. In fact, because the water in an aquaponics system is so full of healthy biology, it is recommended that if possible, you never discharge the water from your fish tank. The only reason why you ever would is if something caused extreme amounts of ammonia to overwhelm your biofilter's ability to convert it and you therefore needed to do a partial water change to dilute the ammonia. An example of this would be a dead, decomposing fish that you were unaware of. Even if such a rare event were to occur, the discharge from your aquaponics system is completely organic and will only benefit any soil lucky enough to be watered by it.

**Climate Change: Aquaponics vs. Traditional Agriculture**

An aquaponics system is a food-growing system that could have zero impact on our environment, especially if the pumps and heaters are powered through renewable energy sources. Except for purely wild food-growing systems, such as the ocean, and most permaculture techniques, no other food system that I know of can make that claim.

On the other hand, traditional agriculture is the single largest contributor of $CO_2$ emissions, while simultaneously contributing to the ongoing shrinking of the earth's $CO_2$ filter through the need for more and more land for growing crops and raising cattle. The main pollutant sources are $CO_2$ emissions from all the petroleum being used in farm production and food transportation, methane from cattle production, and nitrous oxide from over-fertilizing. Aquaponics requires none of these inputs. Petroleum needs in aquaponics range from much less to zero. Fish don't produce methane as cattle do, and there is no chance of over-fertilizing an aquaponics system.

**Aquaponics in the City’s old Factory and Warehouses:**

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Perhaps most importantly, aquaponic systems can be started anywhere. So now instead of clearing jungles and forests we can instead focus on our urban centers and begin to think of old factory and warehouse buildings as the farms of our future. While perhaps not suited to growing vast fields of grain, aquaponics can now grow any vegetable and many types of fruit crops, and do it in a way that is even more productive on a square foot basis, even in an urban setting.
Aquaponics can produce 50,000 pounds of tilapia and 100,000 pounds of vegetables per year in a single acre of space. By contrast, one grass-fed cow requires eight acres of grassland. Another way of looking at it is that over the course of a year, aquaponics will generate about 35,000 pounds of edible flesh per acre, while the grass-fed beef will generate about 75 pounds in the same space.

**Being Self-Sufficient in the City**
Is the notion of producing at least some portion of our food in our urban centers a science fiction fantasy? Not at all. In fact, in her essay "Reconsidering Cities," author Sharon Astyk pointed out that it isn't as unusual as you might think for city dwellers to grow a meaningful portion of the food they eat. She explains that Hong Kong and Singapore already both produce more than 20 percent of their meat and vegetables within the city limits.
In 2002, with more than six million people, Hong Kong was producing 33 percent of the produce, 14 percent of the pigs, 36 percent of the chickens and 20 percent of the farmed fish eaten in the city limits.

**Benefits of Hydroponic Gardening vs (Growing Vegetables in Soil)**

A branch of agriculture, hydroponics is a soil-free method used to grow many types of plants. Depending on the type of hydroponic system used, the plants' roots are suspended in, flooded with or misted with nutrient-rich water that provides them with all the nutrients they need for healthy growth. While the history of hydroponic gardening is believed to date back to at least 600 B.C., in our society this soil-less method of growing plants has really taken off only recently.
Below, we take a look at some of the benefits of hydroponic gardening (vs soil-based gardening). Many of these benefits also apply to aquaponics, a type of food production method that combines aquaculture, i.e. raising aquatic animals such as fish, and hydroponics. (If you're interested in learning more about how you can use aquaponics to produce food in your own home, see aquaponic fish tanks & herb growing kits).

**Benefits of Hydroponics vs. (Soil-Based Methods)**

It's a great way grow plants in places where space is at a premium.

Hydroponics offers both commercial vegetable growers and home gardeners to grow food in places where traditional agriculture is not possible or cost-effective. As the water used in hydroponic gardening is recycled and reused, and no water goes to waste, areas with arid climates or limited water supplies can greatly benefit from this method, and people in those areas will be able to enjoy fresh, locally grown produce. Hydroponic systems are also useful in urban areas where little space is available as hydroponically-grown plants don't need space for developing large root systems to get access to the nutrients they need – all the nutrients they need are readily available in the growing liquid. With Aero Garden' hydroponic indoor cherry tomato growing kit equipped with LED lights, for example, you will be able to grow healthy and nutritious cherry tomatoes even in a small city apartment.

**Chemical-free, eco-friendly farming at its best**

Organic farming is booming as people are worried about harmful pesticides and other unnatural chemicals getting into their bodies and causing health problems. One of the best things about hydroponic farming is that it requires little or no pesticides as weeds, soil-loving bugs and plant diseases that spread in soil are eliminated. The uptake of nutrients by plants grown in hydroponic systems is also higher compared with plants grown in soil, so the use of fertilizers can be reduced dramatically. All of this means cost-savings to hydroponic farmers, but also cleaner food and a cleaner environment.

**Shorter harvest times and higher yields**

Not only does the efficient uptake of nutrients by hydroponically-grown plants reduce the need for fertilizers, it also shortens the harvest time, meaning you will get more crops our of your hydroponic garden per year than you would from a traditional soil-based vegetable garden. As explained above, plants that are grown hydroponically have direct access to water and nutrients, and therefore, they don't have to "waste" energy developing extensive root systems to get the nutrients they need. Instead, the plants can focus their energy on developing the foliage and the fruit.

**It's time-tested – and NASA-tested**

If you're skeptical about switching from soil-based gardening to hydroponics, know this: Even though the term hydroponics was only coined in the 1930s, the use of nutrient-rich water as a growing medium for plants has a very long history. It is believed that the ancient Babylonians used hydroponics for their famous hanging gardens which were built around 600 B.C., and during the 10th and 11th centuries, the Aztecs developed a system of floating gardens based on the principle of hydroponics. In the modern world, hydroponic farming is successfully used around the world, from Japan to Holland, from Australia to Canada. Aquaponics, which

combines aquaculture (raising fish) with hydroponics, has also been tested extensively by NASA scientists who are looking for ways to produce nutritious food in the space.

**Plants in aquaponics**

This chapter discusses the theory and practice needed for successful plant production in aquaponic systems. First, it highlights some of the major differences between ground-grown crop production and soil-less crop production. Following this, there is a discussion on some essential plant biology and plant nutrition concepts, focusing on the most important aspects for aquaponics. After, there is a brief section on recommendations for selecting vegetables to grow in aquaponic units. The final two sections cover plant health, methods to maintain plant health, and some advice on how to make the most of the plant growing space.

In many commercial aquaponic ventures, the vegetable production is more profitable than the fish. However, there are exceptions, and some farmers earn more from particularly valuable fish. Estimates from commercial aquaponic units predominantly in the West suggest that up to 90 percent of the financial gains can come from plant production. One reason is the fast turnover rate of vegetables compared with the fish.

## 6.1 Major differences between soil and soil-less crop production

There are many similarities between in-ground soil-based agriculture and soilless production, while the basic plant biology is always the same (Table 1). However it is worth investigating major differences between soil and soil-less production in order to bridge the gap between traditional in-ground practices and newer soil-less techniques. Generally, the differences are between the use of fertilizer and consumption of water, the ability to use non-arable land, and overall productivity. In addition, soil-less agriculture is typically less labour-intensive. Finally, soil-less techniques support monocultures better than does in-ground agriculture intensive in-ground cultivation. However, farmers cannot fully control the delivery of these nutrients to plants because of the complex processes occurring in the soil, including biotic and abiotic interactions. The sum of these interactions determines the availability of the nutrients to the plant roots. Conversely, in soil-less culture, the nutrients are dissolved in a solution that is delivered directly to the plants, and can be tailored specifically to plants' needs. Plants in soil-less culture grow in contained inert media. These media do not interfere with the delivery of nutrients, which can occur in soil. In addition, the media physically support the plants and keep the roots wet and aerated. Moreover, with in-ground agriculture, some of the fertilizer may be lost to weeds and runoff, which can decrease efficiency while causing environmental concerns. Fertilizer is expensive and can make up a large part of the budget for in-ground farming.

The tailored management of fertilizer in soil-less agriculture has two main advantages. First, minimal fertilizer is lost to chemical, biological or physical processes. These losses decrease efficiency and can add to the cost. Second, the nutrient concentrations can be precisely monitored and adjusted according to the requirements of the plants at particular growth stages. This increased control can improve productivity and enhance the quality of the products.

### 6.1.2 Water use

Water use in hydroponics and aquaponics is much lower than in soil production. Water is lost from in-ground agriculture through evaporation from the surface, transpiration through the leaves, percolation into the subsoil, runoff and weed growth. However, in soil-less culture, the only water use is through crop growth and transpiration through the leaves. The water used is the absolute minimum needed to grow the plants, and only a negligible amount of water is lost for evaporation from the soil-less media. Overall, aquaponics uses only about 10 percent of the water needed to grow the same plant in soil. Thus, soil-less cultivation has great potential to allow production where water is scarce or expensive.

### 6.1.3 Utilization of non-arable land

Owing to the fact that soil is not needed, soil-less culture methods can be used in areas with non-arable land. One common place for aquaponics is in urban and peri-urban areas that cannot support traditional soil agriculture. Aquaponics can be used on the ground floor, in basements (using grow lights) or on rooftops. Urban-based agriculture can also reduce the production footprint because transport needs are greatly reduced; urban agriculture is local agriculture and contributes to the local economy and local food security. Another important application for aquaponics is in other areas where traditional agriculture cannot be employed, such as in areas that are extremely dry (e.g. deserts and other arid climates), where the soil has high salinity (e.g. costal and estuarine areas or coral sand islands), where the soil quality has been degraded through over-use of fertilizers or lost because of erosion or mining, or in general where arable land is unavailable owing to tenure, purchase costs and land rights. Globally, the arable land suitable for farming is decreasing, and aquaponics is one method that allows people to intensively grow food where in-ground agriculture is difficult or impossible.

### 6.1.4 Productivity and yield

The most intensive hydroponic culture can achieve 20–25 percent higher yields than the most intensive soil-based culture, although rounded down data by hydroponic experts claim productivity 2–5 times higher. This is when hydroponic culture uses exhaustive greenhouse management, including expensive inputs to sterilize and fertilize the plants. Even without the expensive inputs, the aquaponic techniques described in this publication can equal hydroponic yields and be more productive than soil. The main reason is the fact that soil-less culture allows the farmer to monitor, maintain

### 6.1.5 Reduced workload

Soil-less culture does not require ploughing, tilling, mulching or weeding. On large farms, this equates to lower reliance on agriculture machinery and fossil fuel usage. In small-scale agriculture, this equates to an easier, less labour-intensive exercise for the farmer, especially because most aquaponic units are raised off the ground, which avoids stooping. Harvesting is also a simple procedure compared with soil-based agriculture, and products do not need extensive cleaning to remove soil contamination. Aquaponics is suitable for any gender and many age classes and ability levels of people.

### 6.1.6 Sustainable monoculture

With soil-less culture, it is entirely possible to grow the same crops in monoculture, year after year. In-ground monocultures are more challenging because the soil becomes "tired", loses fertility, and pests and diseases increase. In soil-less culture, there is simply no soil to lose fertility or show tiredness, and all the biotic and abiotic factors that prevent monoculture are controlled. However, all monocultures require a higher degree of attention to control epidemics compared with polyculture.

### 6.1.7 Increased complication and high initial investment

The labour required for the initial set-up and installation, as well as the cost, can discourage farmers from adopting soil-less culture. Aquaponics is also more expensive than hydroponics because the plant production units need to be supported by aquaculture installations. Aquaponics is a fairly complex system and requires daily management of three groups of organisms. If any one part of the system fails, the entire system can collapse. In addition, aquaponics requires reliable electricity. Overall, aquaponics is far more complicated than soil-based gardening. Once people are familiar with the process, aquaponics becomes very simple and the daily management becomes easier. There is a learning curve, as with many new technologies, and any new aquaponic farmer needs to be dedicated to learn. Aquaponics is not appropriate for every situation, and the benefits should be weighed against the costs before embarking on any new venture.

TABLE 1: Summary table comparing soil-based and soil-less plant production

| **Category** | | **Soil-based** | **Soil-less** |
|---|---|---|---|
| Production | Yield | Variable, depending on soil characteristics and management. | Very high with dense crop production |
| | Production quality | Dependent on soil characteristics and management. Products can be of lower quality due to inadequate fertilization/ treatments. | Full control over delivery of appropriate nutrients at different plant growth stages. Removal of environmental, biotic and abiotic factors that impair plant growth in soil (soil structure, soil chemistry, pathogens, pests). |
| | Sanitation | Risk of contamination due to use of low quality water and/or use of contaminated organic matter as fertilizer. | Minimal risk of contamination for human health. |
| Nutrition | Nutrient delivery | High variability depending on the soil characteristics and structure. Difficult to control the levels of nutrients at the root zone. | Real time control of nutrients and pH to plants at the root zone. Homogeneous and accurate supply of nutrients according to plants' growth stages. Needs monitoring and expertise. |
| | Nutrient use efficiency | Fertilizers widely distributed with minimum control of nutrients according to growth stage. Potentially high nutrient loss due to leaching and runoff. | Minimal amount used. Uniform distribution and real time adjustable flow of nutrients. No leaching. |
| Water use | System efficiency | Very sensitive to soil characteristics, possible water stress in plants, high dispersal of nutrients. | Maximized, all water loss can be avoided. Supply of water can be fully controlled by sensors. No labour costs for watering, but higher investment. |
| | Salinity | Susceptible to salt build up, depending on soil and water characteristics. Flushing salt out uses large amounts of water. | Depends on soil and water characteristics. Can use saline water, but needs salt flush-out that requires higher volumes of water. |
| Management | Labour and equipment | Standard, but machines are needed for soil treatment (ploughing) and harvesting which rely on fossil fuels. More manpower needed for operations. | Expertise and daily monitoring using relatively costly equipment are both essential. High initial set-up costs. Simpler handling operations for harvest. |

### 6.1.7 Increased complication and high initial investment

Variable, depending on soil characteristics and management. Very high with dense crop production. Production quality Dependent on soil characteristics and management. Products can be of lower quality due to inadequate fertilization/ treatments. Full control over delivery of appropriate nutrients at different plant growth stages. Removal of environmental, biotic and abiotic factors that impair plant growth in soil (soil structure, soil chemistry, pathogens, pests). Sanitation Risk of contamination due to use of low quality water and/or use of contaminated organic matter as fertilizer. Minimal risk of contamination for human health. Nutrition Nutrient delivery High variability depending on the soil characteristics and structure. Difficult to control the levels of nutrients at the root zone. Real time control of nutrients and pH to plants at the root zone. Homogeneous and accurate supply of nutrients according to plants' growth stages. Needs monitoring and expertise. Nutrient use efficiency Fertilizers widely distributed with minimum control of nutrients according to growth stage. Potentially high nutrient loss due to leaching and runoff. Minimal amount used. Uniform distribution and real time.

**An Alternative to Traditional Farming: Aquaponics**

With the increasing demand for sustainable and environmentally friendly agricultural solutions, more individuals are turning to and investing in the Aquaponics system. The aquaponics system is a financially viable and eco-friendly option as its water consumption is far less than that used with conventional farming methods. Aquaponics is the symbiotic relationship between fish farming and hydroponics, which enables food to be grown all year round without soil.

Getting started with an aquaponics system can cost anywhere from $800 to $6,000, but the benefits seem to far outweigh the initial start-up capital. Systems can be started for small individual home use, or larger commercial ones are available as well. With one gallon of water in your fish tank, you can have a grow bed that is ½ to 1 sq feet of grow space, and one lb of fish requires roughly 10 gallons of water. The most popular fish that people decide to use for their aquaponics system is Tilapia, while some other individuals have opted to go with catfish, trout, or some other variety. The system can be setup indoors or outside, and food can be grown all year.

To get started, the system does require reliable access to electricity and water, and will continuously require careful water quality monitoring. Aquaponics is showing to be the best of both hydroponics and aquaculture, it is increasingly described as being more efficient than traditional soil based farming and gardening. Although urban homesteading can sometimes make more economic and ecological sense . With the growing trend of conscious consumers, it isn't surprising that more individuals are opting for a convenient, and sustainable, solutions which gives them direct control over what goes into the food that their families are eating.

**Traditional gardening to improve household food security**

**W**hether they are known as home, mixed, backyard, kitchen, farmyard, compound or homestead gardens, family food production systems are found in most regions of most countries worldwide. They may be the oldest production system known and their very persistence is proof of their intrinsic economic and nutritional merit. Traditional tropical gardens typically exhibit a wide diversity of perennial and semi-perennial crops, trees and shrubs, well adapted to local microclimates and maintained with a minimum of purchased inputs. Studies on traditional mixed gardens have emphasized their ecologically sound and regenerative characteristics, by which they "recreate natural forest conditions" and minimize the need for crop management (UNICEF, 1982). The dynamic role of home gardening in family nutrition and household welfare must be assessed in the context of the wider farming system and household economy. Usually, the functions and output of the home garden complement field agriculture. Whereas field crops provide the bulk of energy needed by the household, the garden supplements the diet with vitamin-rich vegetables and fruits, energy-rich vegetable staples, animal sources of protein and herbs and condiments.

Some studies indicate that gardening is not cost-effective as a nutrition intervention as compared with fortification, supplementation and targeted subsidies (Popkin *et al*., 1980;
Brownrigg, 1985). Another common criticism is that gardening is only feasible for households with access to land, water and technical assistance, leaving out many of the food insecure. Further, opponents claim that homestead production is often embraced as a panacea for food insecurity, when in fact it has proved unreliable as a steady source of food and income for poor households.

Advocates of gardening cite evidence that home gardening can be a sustainable strategy for improving food security and incomes when gardens are well adapted to local agronomic
and resource conditions, cultural traditions and preferences (Midmore, Niñez and Venkataraman, 1991; IIRR, 1991). This type of gardening is accessible to the poorest people since it relies on low-cost, low-risk technology and may be adapted to hostile environments (e.g. dryland gardens, flooding gardens). Landless households also benefit from simple hydroponics, container gardening and community or school gardening.

Finally, proponents note that comparative cost-effectiveness studies tend to focus on narrow achievements, such as reduction in vitamin A deficiency, and fail to account for the full array of home gardening benefits. Were these benefits considered, the benefit/cost ratio of gardening projects would be likely to compare more favourably with alternative interventions. Moreover, in terms of alleviating food insecurity, advocates claim that food production controlled by households is more reliable and sustainable than nutrition
interventions that rely on government goodwill and financial support (Niñez, 1984; Von Braun *et al.*, 1993; Moskow, 1996).

Supporters of gardening do not refute the evidence on mismanagement of gardening projects. Many believe that mismanagement and lack of sustainability are largely results of failure to invest the necessary resources in understanding the existing garden system in the context of changing household objectives (Niñez, 1984;

Brownrigg, 1985; UNICEF, 1982; Midmore, Niñez and Venkataraman, 1991). Therefore, "improved" gardens are planned and developed for which the effort and costs for the household often outweigh the benefits, leading to eventual abandonment of the gardens after the project subsidies terminate. Were the improved gardens to build on the characteristics and objectives of traditional gardens in the region, many resource constraint problems could be anticipated and avoided.

Thus, Traditional farming at some level is a production system that the poor can easily enter. Gardening provides a diversity of fresh foods that improve the quantity and quality of nutrients available to the family.

Households with gardens typically obtain from them more than 50 percent of their supply of vegetables and fruits (including such secondary staples as plantains, cassava, taro and sweet potato), medicinal plants and herbs; those households having garden systems that include animal-raising also obtain their primary and often only source of animal protein (Soleri, Cleveland and Frankenberger, 1991; Marsh and Talukder, 1994; UNDP, 1996). Very small mixed vegetable gardens can provide a significant percentage of the recommended dietary allowance for protein (10 to 20 percent), iron (20 percent), calcium (20 percent), vitamin A (80 percent) and vitamin C (100 percent) (Marsh and Talukder, 1994; AVRDC, 1983-1989). Homestead production is also an important source of supplementary income for poor rural and urban households around the world. The combined value of garden production, including sale of surplus vegetable produce and animal products combined with savings in food and medical expenses, varies seasonally but constitutes a significant proportion of total income (upwards of 20 percent) for many households. The garden may become the principal source of household food and income during periods of stress, e.g. the pre-harvest lean season, harvest failure, prolonged unemployment, health or other disabilities suffered by family members or agricultural and economic disruption caused by war. For instance, in Kampala, Uganda, after the civil war, traditional urban agriculture substantially fed the city in non-cereal foods (UNDP, 1996). Also, in Baghdad, Iraq and Sarajevo, Bosnia and Herzegovina, in the 1990s, residents have relied on traditional gardening to provide for many of their nutritional needs (UNDP, 1996).

**Work towards an integrated food security strategy**

Traditional gardening is only one of the possible interventions for enhancing food security for the poor, and it should be considered in the context of a broader national food
security strategy. Indeed, the complex synergies of food availability, access, consumption and nutritional status with poverty, health, mental ability, productivity and economic development demand an integrated approach to solving food insecurity in the long term. Traditional gardening has a special role in this strategy, in providing direct access to food through
self-reliance rather than dependence on externally supported programmes such as food-for-work, targeted subsidies and supplementation and fortification schemes, none of which can
be counted on for sustained support.

"The basic concept of Traditional gardening as a strategy to help resolve the food crisis is the opposite of a relief food grant approach. It requires participation, and that people work for themselves. But it also demands as a precondition that people have access to certain
productive resources; that they not be denied access to a piece of land, or water, or advice from government extension agents, or be forbidden to trellis beans from the balcony of their housing project homes" (Brownrigg, 1985).

**Apartment Balcony Gardens**

The modern day grocery stores, as we know them, have only really been around for the last seventy years or so. Before that, people ate what they grew or bartered for. Chain supermarkets exploded around the 1920s but at that time were small counter service stores. They were operated by two or three employees and most often had no meat or produce departments. Grocery shopping required at least a stop by the supermarket and a second stop at the butcher. By the 1940s the supermarkets had evolved into something that more closely resembles what we know today, complete with a meat and produce department.

Since the development of the modern day supermarket, there has also been a significant population explosion and an ever increasing demand for protein. Additionally, the demand for money and profits by the people at the top of the food chain has forced the hand of agriculture. Now there are things in our food that we can't pronounce and probably shouldn't eat, to say the least. These synthetic additions to our "food" are necessary to make it last longer on the grocery store shelves and increase the profits of the right wing bureaucrats at the top of the food chain. Fish are farmed and fed hormones to make them grow faster. Cows are fed corn instead of grass, and they have come up with very creative ways to stretch the almighty dollar.

**A Safe Effective Alternative**

So, what is a safe, effective alternative to get some natural back into your food? Some natural protein, natural greenery, and all that stuff we now have to pay extra for at the store is what I'm talking about. Well there are a couple of alternatives and the good news is that you don't have to live way out in the country to do it. You don't even have to live next door to an empty lot in the city like on "The Magic School Bus." One realistic, innovative, and effective solution is an apartment balcony garden.

Apartment balcony gardens are not necessary huge elaborate set ups. They are made to be effective and efficient. They can be as pretty or as rustic as you want them to be. Most successful apartment balcony gardens utilize and aquaponics design. Aquawhat? Aquaponics is a system of aquaculture (water life) where the fish you raise in a medium to large size tank, supply the nutrients for the related plants, which in turn, purify the water. I know it sounds elaborate but it really isn't, unless you want it to be.

**Why it's Better**

This is the perfect system for an apartment balcony garden because it gives someone the chance to raise at least a portion of their food, even without a yard or any landscaping at all. Since the system can be as elaborate or as small as you want, it usually works with most any sized balcony. Most balconies have plenty of air and sunlight which are the main two necessities from the environment to allow this system to thrive.

There are many great benefits to having an apartment balcony garden, especially if its aquaponics. One awesome benefit is that everything grown there has been done so without the use of chemicals, so it's better for you. There are no pesticides, no carcinogens, and no preservatives. This means the food is actually healthier for you to eat. It will also taste better and it is fresher. Another great benefit is that it will save you some money. Knowing that dinner is right out on the balcony means you'll be stopping by the store a lot less often.

If you have been looking for a healthy alternative to consider, think about aquaponics in your apartment balcony garden. It is a healthier choice for you and the environment. On top of that, it will help line your pockets which are the important ones. Do a little of your own research and I'm sure you'll agree. An apartment balcony garden is the way to go. Living in an apartment is not a setback, it's just an avenue.

**Some possible applications and development opportunities**

Notwithstanding this rather negative overall appraisal, there may be opportunities for specific kinds of aquaponics initiatives in some locations, so long as the key features and risks associated with these systems as described above are fully understood at the outset.

Small-medium scale vertically integrated production/restaurant/retail/resort. In Europe and the US the most successful aquaponics ventures are those where the aquaponic venture is combined with other "visitor attractions" and/or an organic/ local produce shop and/or café or restaurant. The Pacific version of this model might be an aquaponics café/shop in or close to significant urban and tourism centres and/or aquaponics directly linked to a resort, especially on water deficient islands where fresh vegetables are difficult to source. In this case the resort or café fully understands the production limitations and risks, but exploits the intuitive appeal of aquaponic systems. Staff are also likely to be permanently on hand to deal with routine care and maintenance of such systems at limited marginal cost. Again this might be done with either hydroponics or aquaponics but the tourist appeal of the latter is likely to be greater.

Education and social development in small institutions. In so far as an aquaponic system is a microcosm of a freshwater (potentially marine) ecosystem, and illustrates many of the essential processes of life and "ecosystem services" it serves as an excellent educational and skills development tool. The complexity of management and the requirements for dedicated husbandry and significant planning and organisational skills – while being a disadvantage from a commercial perspective – may be considered an advantage when seeking to strengthen communities, team work, and responsibility. As such, the development of aquaponic systems in schools, communities, prisons, military camps etc. may meet a range of other needs while at the same time generating some healthy locally produced food. Again the rationale and opportunity for this will be greater in water and soil deficient islands. There is however a significant risk that such systems will nonetheless break down once the initial flush of enthusiasm is over, and without a strong commercial incentive to maintain efficient production. The absence of a determined "champion", limited access to high quality cheap fish food, and high costs of electricity are also likely to be a significant constraints on longer term success.

Household scale production may have some potential in water/soil deficient islands, or where people are sufficiently wealthy that investment in backyard gardening becomes a worthwhile hobby activity in its own right. Relatively simple "2 bucket" backyard designs may be fairly robust and resilient, so long as feed inputs are kept below some basic operating thresholds, and so long as Tilapia (or possibly catfish) are available. The main constraint here will be energy cost and energy/equipment reliability. Operating costs may be reduced through investment in solar panels/wind turbines and batteries, and reliability can be addressed through investment in monitoring systems and backup. In most cases however small scale hydroponic systems are likely to serve this need better at least in the first instance. These may be upgraded to aquaponic systems once skills have been developed, and if there is demand for fish and a ready supply of high quality fish feed and seed.

**CONCLUSIONS**

Aquaponics is a seductive concept which is especially appealing to those seeking to promote more sustainable food production systems. It involves the production of both fish and vegetables, using a single nutrient source – fish feed – and ensures that most of the wastes that would normally be released from intensive fish culture are instead used to grow vegetables. It is important to recognise however that aquaponic systems are primarily *vegetable production systems*, simply because of the biological nature of the relationship between fish nutrient production and plant nutrient uptake. Intensively grown fish produce a lot of nutrients, the consumption of which requires a large amount of plant production. This is particularly the case if part of the enterprise objective is to minimise solid waste disposal to the environment. In several of the more commercial systems operating at the present time, the fish are regarded as "organic nutrient generators", rather than as an important product in their own right. The primary advantage of aquaponics, shared with some forms of hydroponics, is water use efficiency. Other oft-cited advantages include nutrient utilization efficiency, product quality and food security. These latter are undermined to some degree by the use of high quality high protein (usually fishmeal based) fish feed as nutrient source in the more efficient and productive systems, and/or the need to add nutritional supplements.

A further possible advantage lies in the complex organic nature of the aquaponic nutrient solution compared with the relatively simple chemical based solutions used in hydroponics. There is some evidence to suggest that this has pro-biotic properties, promoting nutrient uptake, protecting against some disease, improving product flavour and extending shelf life. Against these advantages must be set significant disadvantages, especially from a business or enterprise perspective. Integrating recirculating aquaculture with hydroponic plant production increases complexity, compounds risk, compromises system optimisation for either product, restricts management responses – especially in relation to pest, disease and water quality - and constrains marketing. Energy use is relatively high because of the need for both aeration and pumping in most systems. Capital and fixed operating costs are also high, increasing financial exposure should production fail to reach design targets. System failure may result in a two month restart and rebalancing period. Given that most aquaponic systems are dominated by plant production this is a heavy price to pay.

Aid agencies should be extremely cautious about supporting aquaponics initiatives, and should undertake thorough local feasibility studies before investing in any demonstration systems or support programmes. Such assessments should consider carefully whether aquaponics in a particular location will have any real advantages over hydroponics and/or stand-alone aquaculture production systems (or indeed fisheries) as a means of generating high quality food in water and soil deficient islands; and whether the skills, knowledge and dedication are available to sustain viable aquaponics. In any case, given the complexity of the systems it is arguable that aquaculture and/or hydroponic systems should be introduced first, and if successful may be combined with the other component at a later date, if local physical and economic conditions favour such integration.

**The way forward**

Aid agencies and NGOs should be extremely cautious about supporting aquaponics initiatives. The focus of development activity should not be on the promotion of aquaponics per se; rather on raising awareness of the range of options available to enable vegetable (and in some cases fish) production in water and soil deficient islands, and facilitation of local initiatives aimed at overcoming these constraints.

Where aquaponics appears to be an attractive option, thorough local feasibility studies should be undertaken before investing in any demonstration systems or support programmes. Such assessments should consider carefully whether aquaponics in a particular location will have any real advantages over hydroponics and/or stand-alone aquaculture production systems (or indeed fisheries) as a means of generating high quality food in water and soil deficient islands; and whether the skills, knowledge and dedication are available to sustain viable aquaponics. In any case, given the complexity of the systems it is arguable that aquaculture and/or hydroponic systems should be introduced first, and if successful may be combined with the other component at a later date, if local physical and economic conditions favour such integration.

To date, aquaponics has been primarily pursued by aquaculturists through aquaculture/fisheries agents, despite the fact that it is primarily a horticultural activity. There needs to be a rebalancing of effort and support, primarily through agricultural training and extension, but also through joint initiatives of fisheries and agriculture services where appropriate

To date integration of recirculating aquaculture and hydroponics has been promoted as a “good thing”, almost as an article of faith. It is essential that in future the disadvantages of integration – at least in the current economic and marketing climate – are also fully understood.

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# MATHEMATICAL IN COMPUTER SCIENCE

**Hieu Vu, Ph.D.**

American University of Nigeria

98 LamidoZubairu Way

Yola by Pass, P.M.B. 2250,

Yola, Adamawa State, Nigeria

**Abstract**

*Mathematics has been known for proving services for the other fields. We all learned mathematics from early childhood, and it is a very important skill in problem solving. Mathematics penetrates deeper in scientific disciplines such as: engineering, physics, statistics, etc… and computer science is not an exception.Some mathematics courses are taught by computer science professors and listed under computer science curriculum.*

Keywords

Computer science, Mathematics, Algorithms, Numerical Analysis, Discrete Mathematics, Computer Logic

## I. INTRODUCTION

The great ancient Greek philosopher Aristotle (384-322 BC) defined mathematics as "The science of quantity", and this definition held until the 18th century. Starting in the 19th century, the study of mathematics increased and introduced the concept of abstract topics: group theory and projective geometry which made no distinct between quantity and measurement. Today the only distinction in Mathematics is "Pure mathematics" and "Applied mathematics"[1]

Mathematics is regarded throughout the world as an essential tool, the key to open the doors for other fields, such as engineering, natural science, finance, physics, statistics, etc…It is obvious that without mathematics contributions, science and technology cannot advance.

We all know, no matter on what type of professions, we have been using some form of mathematics on our daily job. It could involve a simple calculation, computing, or studying, analyzing an engineering blueprint or a spreadsheet, and general problem solving…This research paper presents the important role of mathematics in the field of computer science.

## II. THE ROLE OF MATHEMATICS IN COMPUTER SCIENCE

Computer science has root from mathematics, the Atanasoff-Berry computer (ABC) was the first automatic electronic digital computer. Some historians believed mathematics and physics professor John Vincent Atanasoff from Iowa State College built the ABC computer with the help of graduate student Clifford Berry, hence they named the electronic digital device "Atanasoff-Berry computer". Conceived in 1937, the machine was designed to solve systems of linear equations, not programmable, and was sucessfully tested in 1942. According to Mollenhoff in 1988 "Atanasoff: Forgotten Father of the Computer" published by Iowa State University Press. [2]

To understand the role of mathematics in computer science, there are some questions arise about the relationship between the two fields.

1. What is Computer Science? One definition of computer science is "The study of algorithms". An algorithm defines a finite sequence of rules how to produce an output of information from a given input. In fact no two computer scientists would give the same definition, the same for two mathematicians in defining mathematics.

2. Is Computer Science part of Mathematics? In the early days, computer science was a small group of professors and students that was housed inside mathematics department. Today computer science courses are actively studied by computer science students. But if we focus on the study of algorithms then computer science merely be a branch of mathematics, isn't it?

3. How Mathematics and Computer Science interact? Computer science affects mathematics in many ways. Computers can be used for computing in mathematical research when manual computations are too difficult, time consuming and error prone. Also, there are some connections between computer science and mathematics in the areas of numerical analysis, logic, and number theory. [3]

## III. MATHEMATICAL STUDIES IN COMPUTER SCIENCE

In many universities across the U.S. and the world, computer science curriculum usually includes some real mathematics courses such as Discrete Mathematics, Numerical Analysis, and math-oriented course such as Digital Logic (Boolean Algebra).

### III. 1. DISCRETE MATHEMATICS

Discrete mathematics provides the mathematical foundations for several computer science courses such as: algorithms, automata, data structures, database theory, computer security, and operating systems.

- Logic: mathematical reasoning, the rules of logic gives precise meaning to a mathematical statement. Logic has many applications to computer science: rules are used in the design of computer circuit, computer program's construction, the verification of program's correctness… Prolog (Programming Logic) was developed in the 1970s by computer scientists working in the area of artificial intelligence (AI).

- Algorithms: the study of algorithms can be used to solve many different types of problems. The two most important problems in computer science are searching for an element in a list, and sorting the list into order.

Example 1: Finding the Maximum element in a finite sequence

```
procedure max(a1, a2, …, an: integers)
      max := a1
      for i := 2 to n
            if max <ai then max := ai
      return max {max is the largest element}
```

Example 2: The Linear Search algorithm

```
procedurelinearSearch(x: integer, a1, a2, …, an: distinct integer)
      i := 1
      while(i ≤ n and x ≠ ai)
            i := i + 1
      if i ≤ n then location := i
      else location := 0
      return location {location is the subscript of the item = x}
```

Example 3: The Binary Search algorithm

```
procedurebinarySearch(x: integer, a1, a2, …, an: ascending integers)
i := 1 {i is the left endpoint of search interval}
j := n {j is the right endpoint of the search interval}
while i < j
m := (i + j) / 2
if x > am then i := m + 1
else if x < am then j := m − 1
else return m   {location found}
return 0            {location not found}
```

Example 4: The Bubble Sort algorithm

```
procedurebubbleSort(a1, a2, …, an: real numbers with n ≥ 2)
      for i := 1 to n − 1
            for j := 1 to n − i
                  ifaj> aj+1 then exchange two elements
```

Example 5: The Insertion Sort algorithm

```
procedureinsertionSort(a1, a2, …, an: real numbers with n ≥ 2)
      for j := 2 to n
            i := 1
            whileaj>ai
                  i := i + 1
            m := aj
            for k := 0 to j – i – 1
                  aj-k := aj-k-1
            ai := m
{a1, a2, …, an is in ascending order}
```

- Database: most databases are relational databases, from mathematical concept “Relations” which are the relationships between elements of a set. Tables in a relational database deal with relationships such as a person (customer) and his/her telephone number.

Example: Table Students which contains student records

```
(Student_name, ID_number, Major, GPA)
(Ackerman, 123456, Computer Science, 3.8)
(Chou, 888324, Mathematics, 3.45)
(Adams, 231455, Physics, 3.70)
(Stevens, 789654, Psychology, 2.99)
```

- Computer security: Mathematics provides algorithms for encryption, description, hashing functions to protect the databases, computing environments.

Example: In practice, many hashing functions are used. One of the most common is:

```
h(k) = k mod m
h(064212848) = 064212848 mod 111 = 14
h(037149212) = 037149212 mod 111 = 65
```

[4]

III. 2. NUMERICAL ANALYSIS

Numerical analysis is the study of how functions, derivatives, integrals, and differential equations are handled as a string of numbers in a computer system. Numerical analysis also deals with series of expansions such as Taylor series, Fourier series… Mathematicians, computer scientists and engineers have to work with a huge computing tasks and that is why numerical analysis involves deeply with the use of computer for solving problems.

Example 1: The Taylor expansion is:

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots, -\infty < x < \infty$$

Example 2: The Fourier series:

$$f(x) = a_0 + \sum_{n=1}^{\infty} \left( a_n \cos\frac{n\pi x}{L} + b_n \sin\frac{n\pi x}{L} \right)$$

To solve the two problems above (example 1 and 2) which expands to 10 terms is already a tremendous task. This is why numerical analysis requires to use a computer software package such as Mathlab, Linpack, Eispack,…

Example 3: Newton's divided-difference formula:

To obtain the divided-difference coefficients of the interpolatory polynomial P(x), for x indexed from 0 to n ($x_0, x_1, x_2, \ldots, x_n$).

INPUT: numbers $x_0, x_1, \ldots, x_n$: values $f(x_0), f(x_1), \ldots f(x_n)$ as $F_{0.0}, F_{1.0}, \ldots$

OUTPUT: the numbers $F_{0.0}, F_{1.1}, \ldots, F_{n.n}$ where

$$P_n(x) = F_{0.0} + \sum_{i=1}^{n} Fi.j \prod_{j=0}^{i-1}(x - xj \quad (F_{i.j} = f|x_0, x_1, \ldots x_i|)$$

Step 1: for i = 1, 2, …, n

for j = 1, 2, …, i

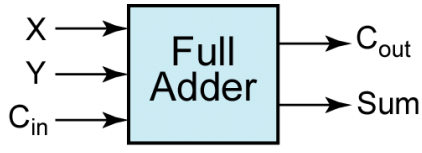
set $F_{i.j} = \dfrac{Fi.j-1 - Fi-1.j-1}{xi - xi-j}$ $(F_{i.j} = f|x_{i-j}, \ldots x_i|)$

Step 2: OUTPUT $(F_{0.0}, F_{1.1}, \ldots, F_{n.n})$

III. 3. DIGITAL LOGIC

Digital circuit technology has changed rapidly. Very Large Scale Integrated (VLSI) circuit chips now can contain millions of transistors. Digital logic theory is applied in the design and analysis of circuit, and Boolean algebra is the basic mathematical tool needed to analyze and synthesize an important class of switching circuit.

Example: Design a binary adder

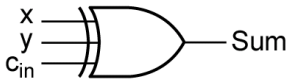


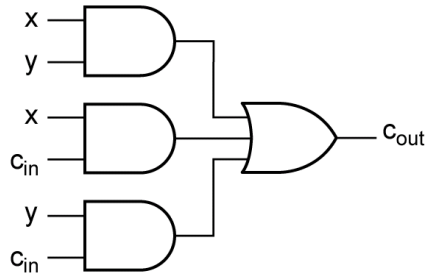

Truth table for a full adder

| X | Y | $C_{in}$ | $C_{out}$ | Sum |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 |

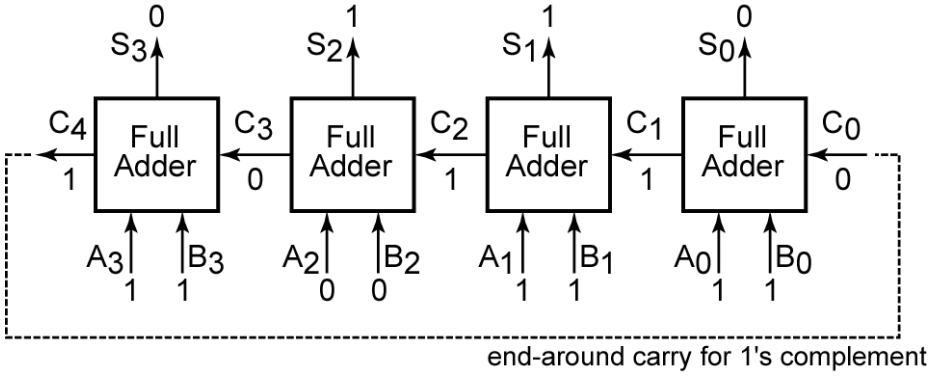
$$\begin{aligned} Sum &= X'Y'C_{in} + X'YC'_{in} + XY'C'_{in} + XYC_{in} \\ &= X'(Y'C_{in} + YC'_{in}) + X(Y'C'_{in} + YC_{in}) \\ &= X'(Y \oplus C_{in}) + X(Y \oplus C_{in})' = X \oplus Y \oplus C_{in} \end{aligned}$$

$$\begin{aligned} C_{out} &= X'YC_{in} + XY'C_{in} + XYC'_{in} + XYC_{in} \\ &= (X'YC_{in} + XYC_{in}) + (XY'C_{in} + XYC_{in}) + (XYC'_{in} + XYC_{in}) \\ &= YC_{in} + XC_{in} + XY \end{aligned}$$



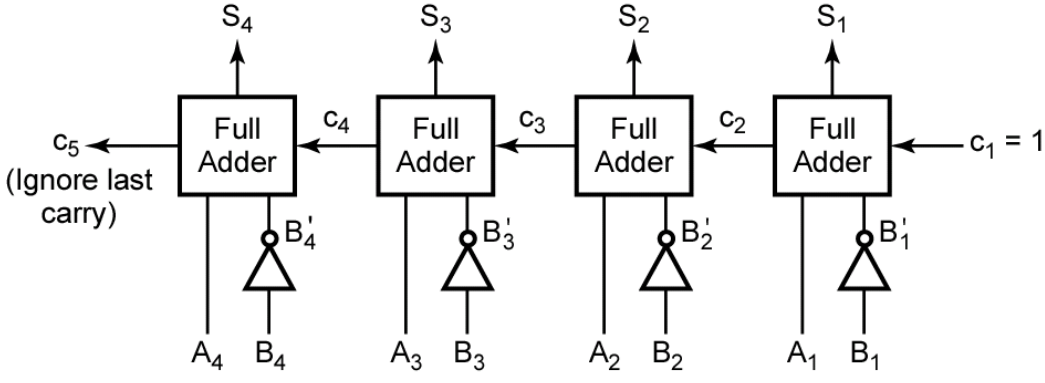




When 1's complement is used, the end-around carry is accomplished by connecting $C_4$ to $C_0$ input.




Binary Subtracter using full adder

Subtraction is done by adding the 2's complemented number to be subtracted




[6]

The 2's complement represents a negative number in binary. It is form by inverting all bits (1's) then add by 1, as you can see in the diagram above. ($c_1 = 1$)

## III. 4. ALGORITHMS

Mathematics provides the capability, effectiveness in problem solving skills. This capability allows computer programmers to build effective algorithms for solving particular problems. Some popular, frequently used algorithms were developed very long time ago by famous ancient Greek mathematicians.

### III. 4. 1. Euclid's algorithm to find the greatest common divisor (GCD)

It is one of the earliest known numerical algorithm developed by Euclid in around 300 B.C. for finding the greatest common divisor (GCD) of two positive integers. Euclid lived in Alexandria during the reign of Ptolemy (323-283 BC) and regarded as the father of geometry.

Let gcd(x, y) be the greatest common divisor of two positive integers x and y.

If x = y, thengcd(x, y) = gcd(x, x) = x

If x > y, then gcd(x, y) = gcd(x-y, y)

Proof:

Suppose that d is a divisor of both x and y, then there exist integers $q_1$ and $q_2$ such that $x = q_1d$, $y = q_2d$. Then

$x - y = q_1d - q_2d = (q_1 - q_2)d$ => d is also a divisor of x – y

In a similar fashion, we can prove that any divisor of x – y and y is also a divisor of x.

Java implementation Euclid'GCD algorithm

```
publicintgcd(int x, int y){
      int p = x;      //preserve original value x, y
      int q = y;
      while(p != q)
            if(p > q)
                  p -= q;
            else
                  q -= p;
      return p;       // or q (p = q)
}
```

III. 4.2. Sieve of Eratosthenes for collecting prime numbers

Eratosthenes (276 – 194 BC) was the third librarian of the famous Alexandria library. He is known for his measurement of the earth's perimeter and estimating the distances to the sun and the moon. In mathematics, he developed an algorithm to collect prime numbers. This algorithm is known as the "Sieve of Eratosthenes"

To find all prime numbers which are smaller than a given number N?
1. Write all integers from 1 to N in order
2. Since 1 is not a prime number so cross it out

Then the algorithm proceeds sequentially in steps, on each step:
3. Find the first number that is not crossed yet, mark it as a prime,
then cross out all of its remaining multiples

Repeat step 3 above while the least available number does not exceed $\sqrt{N}$, because, for a number A = a.b less than or equal to N, the factors a, b cannot exceed $\sqrt{N}$. When the algorithm stops, the prime numbers are not crossed. [8]

Java implementation of Sieve Eratosthenes algorithm

```
public static void getPrimes(int a[]){
for(int i=2; i*i<a.length; i++)
if (a[i] != 0)
for(int j=i+i; j<a.length; j+=i)
a[j] = 0;
}
```

## IV. CONCLUSION

We have been using some form of mathematics in our daily lives, either at work or do some mentally analysis, calculations on a shopping day. Mathematics penetrates into other fields in many different ways such as mathematical models and methods can be used to analyze some particular problems that arise in computer science. [9]

No-one can deny the important role of mathematics in computer science. However, as the computer technology improves rapidly, mathematicians, engineers can now rely on computer to solve their problems, making their works easier, faster, and reliable.

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# Overview of Mobile Spectrum Assignment and Licensing Obligations in Thailand

**Settapong Malisuwan and Nopppadol Tiamnara**
The National Broadcasting and Telecommunication Commission (NBTC), Thailand

## ABSTRACT

*In Thailand, the National Broadcasting and Telecommunications Commission (NBTC) plays a key role in managing the spectrum for telecommunications service and regulating the telecommunications business in Thailand. The licensing policy of mobile service outlines a vision to "develop the telecommunications business, minimize the gap in access to information technology, enhance the country's competitiveness and upgrade Thai people's quality of life." The NBTC has established a policy on spectrum management and use of spectrum which are national communications resources, considering the utmost public benefits at national and local levels in education, culture, State security and other public interests including fair and free competition, as well as the procedures that will ensure thorough and appropriate distribution of benefits to various services and in line with State policy for the development of digital economy. The objective of this paper is to present regulatory background for mobile spectrum assignment and licensing obligations in Thailand.*

**Keywords:** Mobile, Assignment, Spectrum, Thailand

## I. INTRODUCTION

ICT and telecommunications are generally seen as facilitators of growth, especially in terms of labor and multifactor productivity, increased competitiveness and cost reduction across the whole economy. The development of ICT services has also had a dramatic effect on consumer behavior in Thailand, as well as delivering important social benefits.

Basically, having supportive regulatory policy will be a major factor in narrowing the digital divide and lifting the country's competitiveness. Based on the Measuring the Information Society Report 2015 (MIS report 2015) [1], Thailand is ranked 74th out of 167 countries this year, up from 81st last year. NBTC strongly believes the IDI ranking for Thailand will improve to 60th by 2017, based on the fact that the 3G and 4G mobile networks roll-out resulted in a significant improvement in the ranking, to 81st in 2014 from 92nd in 2010 [2]. The target of the NBTC is that Thailand's IDI ranking will be No.1 in ASEAN by 2020. The ITU MIS report 2015 identified Thailand as one of a group of "most dynamic countries" that recorded above-average improvements in their IDI ranking over the past five years. This means that Thailand was the most dynamic country in Asia-Pacific, showing the greatest change in IDI ranking in the region, supported mainly

infrastructure and ICT use but also represented a right direction of Thailand's telecom regulatory policies. To highlight the importance of telecommunications policy, this paper describes regulatory background for mobile spectrum assignment and licensing obligations in the context of ensuring that NBTC policy and regulation-in respect of spectrum and other key inputs to the mobile market-supports the further development of mobile broadband services. This paper organizes the content as follows. Section II explains policy of the spectrum management. Section III describes the telecommunications master plan. Importance regulatory issues are presented in Section IV. The conclusion is the last section.

## II. POLICY OF THE SPECTRUM MANGEMENT

The NBTC has duties, by law, in spectrum management. The objectives of spectrum assignment must be conformed with policy objectives stipulated in relevant laws, particularly the Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services, B.E. 2553 (2010) [3], the Master Plan on Spectrum Management, B.E. 2555 (2012) [4] as well as international theories and principles.

The Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services, prescribes that the permission to use radio frequency for telecommunications service shall be carried out with due regard to maximum public interests at the national, regional and local levels in education, culture, State security and other public interests, including free and fair competition, and shall be carried out in the manner that extensively and appropriately distributing the utilities as the national communications resource to all segments of enterprises for public interest.

Therefore, it is very clear that the policy objectives of spectrum assignment are based on the principle of public interest together with free and fair competition. The NBTC thus set policy objectives for the spectrum auction for telecommunications service in Thailand with the priority as follows [5]:

1) Efficiency of spectrum assignment thereby creating the utmost benefits to the public;
2) Promoting competition in the market with the aim to improve quality of service and reduce costs of services thereby benefiting people at large;
3) Transparency in the spectrum auction which include the auction design and the auction implementation thereby creating common understanding among all stakeholders and the mutual acceptance of the auction results;
4) Development of telecommunications industry in Thailand including the development of infrastructure and services thereby improving capability in supporting the increasing demands in the future;
5) Revenue to State, the revenue arising from the auction should be appropriated for the State benefit.

In granting the spectrum license for telecommunications service, the NBTC strives to achieve the regulatory balance composing of three equally important principles in order to bring about the greatest benefits to the people and the country. These principles are:

1) The most efficiency of spectrum assignment. Since the spectrum is a national communications resource, the

whereby the most efficient spectrum assignment method is the auction. Furthermore, the spectrum assignment must also be able to catch up with the usage demand from both operators and end users;
2) Free and fair competition. The regulation must help creating the regulatory environment that is conducive for market entry and have appropriate competition measures in place to prevent the abuse of market power. The regulation must also be proportionate and not place undue burden to the licensee;
3) State benefits that reflect the value of the resource. The State benefits come in the form of revenues from the spectrum auction and business operation taxes, as well as the socioeconomic benefits and the development brought about by the spectrum utilization.

## III. THE TELECOMMUNICATIONS MASTER PLAN No. 1, B.E. 2555-2559 (2012-2016)

The Telecommunications Master Plan, B.E. 2555-2559 (2012-2016) highlights the public's equal, pervasive and reasonably priced access to diverse telecommunications services through modernized networks on a fair competition basis and with efficient use of telecommunications resources as the core network to support the national development into an intellectual and creative society, with a view to narrowing the rural-urban disparities, continuingly enhancing the country's competitiveness in terms of telecommunications infrastructure, as well as developing efficient consumer protection measures. The Master Plan has been outlined in six aspects as follows [4],[5]:

### (1) Development and Promotion of Free and Fair Competition

Monitoring and ensuring fair business operations in all markets where a monopoly or a reduction or restriction of competition is prevalent, at both national and local levels; and preventing the major operators or the operators with significant market power from abusing their market powers or any single one or group of them from manipulating or distorting market mechanism which could relatively lead to inefficient competition, so as to ensure fair competition and people's access to telecommunications services on a fair and reasonably-priced basis.

### (2) Spectrum Licensing and Business Operation Licensing

Allowing the licensed operators to operate telecommunications services on a free and fair competition basis; encouraging the deployment of modern technologies based on technological neutrality; and coordinating with concerned authorities in the formulation of licensing rules, guidelines and conditions for satellite communication services, in order to promote competition and diversification of telecommunications and broadband services.

### (3) Efficient Resources Utilization

Ensuring the management and approval of efficient telecommunications resources utilization; encouraging infrastructure sharing for the utmost benefit at national and local levels in education, public health, culture, State security and other public interests such as in the case of emergency or disaster breaks out, with due

encouragement of an optimized utilization of telecommunications, radiocommunications and communication satellite resources for the utmost benefit and in conformity with international practices and obligations.

**(4) Universal Basic Telecommunications Services**

Implementing measures to promote operators to make available the universal basic telecommunications services in the target areas; encouraging the provision of basic telecommunications services to the underprivileged in accordance with the plan on universal basic telecommunications services and social services to ensure the access to quality services at a reasonable price; fostering the provision of telecommunications services for social development and quality of life improvement; and promoting the capacity enhancement of telecommunications device and service industry for the disabled and the underprivileged in the society.

**(5) Consumer Protection**

Enhancing the awareness among consumers of their basic rights in telecommunications service, benefits from consuming various types of telecommunications services, needs to keep abreast of technological advancement to ensure their efficient use of services, understanding of their right and freedom in consuming telecommunications services, and efficient access to complaint channels; and devising measures to step up roles of the operators in providing services in an ethical manner and with responsibility for consumers and the society.

**(6) Preparedness for and Entry into the ASEAN Economic Community (AEC) and Promotion of International Cooperation**

Fostering the enhancement of Thailand's potential and readiness for the forthcoming AEC membership in 2015 by developing telecommunications cooperation and linking of infrastructure, rules and regulations, industry sector, researchers and developers, regulating agencies, and the public; and promoting international cooperation under various frameworks at bilateral and multilateral levels with due regard to the national interests.

## IV. IMPORTANT REGULATORY ISSUES

**1. Telecommunications Numbers Management, and Mobile Number Portability and Record of Prepaid Mobile Phone Service's Users**

The NBTC has a policy to allocate telecommunications numbers efficiently and sufficiently for the operators' service provision and network expansion. It recognizes the importance of an allocation of numbers for public services, businesses and for national security, as well as for supporting the emergency or disasters. It has therefore devised a telecommunications numbering plan and the criteria for allocation of telecommunications numbers that is in line with the policy on telecommunications resource management. This means that the

telecommunications resources, are undertaken in an efficient and fair manner and sufficient for the supply of services on the basis of free and fair competition including protection of service users.

The NBTC's current telecommunications numbering plan is designed to cater for the long-term number demand and support future service provision employing innovative technologies. The plan provides various types of telecommunications numbers to support services provided by operators which include fixed line number, mobile number, VoIP number, premium service number, technical number as well as short code number. In addition, the NBTC has been managing the telecommunications number allocation according to the NBTC's Notification regarding the Criteria for Allocation and Management of Telecommunications Numbers, which details the basic principles of telecommunications number management and allocation with a clear and efficient process, including inter alia: guidelines on telecommunications number planning; application procedures for allocation of telecommunications numbers; procedures and criteria for allocation of telecommunications numbers; rights and duties of holder of allocated numbers and regulating guidelines. Besides, the holders of allocated numbers are duty-bound to pay fee for the telecommunications numbers at the rate specified in the Notification.

The other important duty of the NBTC regarding mobile numbers management that gain interest from the public is the regulation of mobile number portability. This operation is under the NBTC's Notification Regarding the Criteria for Mobile number Portability which outlines rules and guidelines for porting mobile number to another network provider while retaining their existing mobile numbers. Such number portability not only benefits the users, but also promotes competition in telecommunications services, improves service quality in order to retain the customers as well as supports the optimum utilization of numbers. The Notification also prescribes an investment in a Clearing House for data collection through a consortium of the mobile service providers, with the investment proportion to be specified.

The NBTC has set forth a rule regarding the record of prepaid mobile phone service's users (prepaid SIM card) under the NBTC's Notification regarding the Criteria for Allocation and Management of Telecommunications Numbers. The NBTC has also determines a guideline on the registration of prepaid mobile phone service's users (prepaid SIM card) to be complied by all mobile operators in order to protect the right of mobile phone users as well as to protect the society and national security. Moreover, there is a requirement that, for new numbers, the mobile operators must register the users' SIM card prior to SIM activation.

**2. Telecommunications Network Interconnection**

In 2013 the NBTC issued the Notification Regarding Telecommunications Network Access and Interconnection B.E. 2556 prescribing criteria and procedures for network interconnection. The Notification requires that a licensee who owns network must allow other licensees to interconnect with its network on a fair, reasonable and non-discriminatory basis [6].

The Notification also requires the licensee who owns network to develop and submit the Reference

interconnection charge. Such interconnection charge must be cost-oriented and calculate on long run incremental cost basis. The charge for necessary facilities for interconnection must also be cost-oriented. The NBTC, however, may impose a certain calculation method and appropriate reference interconnection charge for certain interconnection services.

In addition, this Notification also provides guidelines for contractual arrangements as well as dispute resolution procedure in the case where there is any refusal of network interconnection or access for which the petition should be submitted within one year as from the date of the refusal or the date the dispute regarding network interconnection or access arises. During the dispute settlement process, the NBTC may order temporary access or interconnection following conditions in the existing contract, conditions in the same type of contract or use the calculation method for interconnection charge that the NBTC sees appropriate. In this regard, the NBTC has issued the Notification Regarding Standard Method for Calculating Interconnection Charges B.E. 2556 (2013) to be the calculation standard for the transparency.

Furthermore, in year 2014 the NBTC has issued the Notification Regarding the Reference Interconnection Charges B.E. 2557 (2014) which applies the calculation method according to the Notification regarding the standard method for Calculating Interconnection Charges mentioned-above. The purpose of this Notification is to set fair regulatory guideline and fair interconnection charge for telecommunications service users where an agreement regarding the charges cannot be reached among the licensees, where there is a dispute regarding the charge or where temporary charge is required.

### 3. Telecommunications Network Access

The NBTC's Notification Regarding Telecommunications Network Access and Interconnection B.E. 2556 also prescribes criteria and procedures for network access. The Notification requires that a licensee who owns network must allow other licensees to access to its network on a fair, reasonable and non-discriminatory basis [7].

The Notification also requires the licensee who owns network to develop and submit the Reference Access offer together with supporting document that prescribes principle and method for calculating access charge. Operators are permitted to determine the access rate among themselves via commercial negotiations on a fair, reasonable and non-discriminatory basis. The NBTC, however, may impose a certain calculation method and appropriate reference interconnection charge for certain interconnection services.

In addition, this Notification also provides guidelines for contractual arrangements as well as dispute resolution procedure in the case where there is any refusal of network interconnection or access for which the petition should be submitted within one year as from the date of the refusal or the date the dispute regarding network interconnection or access arises. During the dispute settlement process, the NBTC may order temporary access or interconnection following conditions in the existing contract, conditions in the same type of contract or as the NBTC sees appropriate.

**4. Infrastructure Sharing for Mobile Network**

In order to promote free and fair competition and to bring the quality and efficient service to the consumers, the NBTC has prescribed the Notification Regarding Infrastructure Sharing for Mobile Network B.E. 2556 (2013) which requires the licensee (Type III and the mobile operators under concessions) to permit other licensees to share its own infrastructure for mobile network [8]. The Infrastructure sharing includes tower and mast, base station area, transmission network between base station and base station controller. In sharing its own network, the licensees must treat other licensees on a fair, reasonable and non-discriminatory basis and the infrastructure sharing charge can be determined among licensees on a fair, reasonable and non-discriminatory basis. In addition, this Notification has also prescribed criteria and procedures for contract negotiation and dispute resolution where an agreement cannot be reached among the licensees.

**5. Domestic Mobile Roaming Services**

The NBTC has prescribed the Notification Regarding Domestic Mobile Roaming Services to promote free and fair competition and to enable nationwide service to consumers. This Notification requires the licensees (Type III mobile operators and mobile operators under concessions) to allow other mobile operators to roam on its own network except the licensee network is non-interoperable with the raomer's network due to different standard and technology employed. Furthermore, the licensee must treat other licensees on a fair, reasonable, and nondiscriminatory basis and the domestic mobile roaming charge can be determined among the licensees on a fair, reasonable, and non discriminatory basis as well as must be reasonable comparing with the retail rate paid by its customers. In addition, this Notification has also prescribed criteria and procedures for contract negotiation and dispute resolution where an agreement cannot be reached among the licensees.

**6. Mobile Virtual Network Service**

The NBTC has prescribed the Notification Regarding Mobile Virtual Networks Service B.E. 2556 (2013) to promote free and fair competition as well as to promote market entry for small entrant in order to escalate mobile service competition and provide service alternatives to customers [9]. The Notification requires the licensee (Type III mobile operators and mobile operators under concessions) who is a wholeseller to treat Mobile Network Operators (MVNOs) on a fair, reasonable and non-discriminatory basis and charge can be determined by the agreement between the wholeseller and MVNOs on a fair, reasonable, and non discriminatory basis as well as must be reasonable comparing with the retail rate paid by the wholeseller's customers. In addition, this Notification has also prescribed criteria and procedures for contract negotiation and dispute resolution where an agreement can not be reached among the licensees.

**7. Measure for the Prevention of Monopoly and the Identification of Market Power in Telecommunications Business**

The NBTC implements two types of competition regulation-the ex-ante and ex-post regulation. Ex-post regulation is governed by the NTC Notification on Measures to Prevent Monopolistic and Unfair Competition

among telecommunications service providers and to promote and support competition in and development of the telecommunications industry in an efficient and sustainable manner [10]. The Notification prohibits operators who have been deemed to have Significant Market Power (SMP) from carrying out certain anti-competitive practices such as service subsidization and cross service subsidization for the service or the business under competition in the market, acquisition of business of the same service type; and any conduct deemed as abuse of market power in the manner of monopoly, or reduction or restriction of competition. The Notification also institutes a process of inquiry dealing with the licensee who acts or behaves in such manner, as a standard of practice for the NBTC.

For the ex-ante regulation, in 2014 the NBTC issued two key notifications. The first is the NBTC Notification on Market Definition and Relevant Markets in Telecommunications B.E. 2557 (2014), and the second is the NBTC Notification on Criteria and Procedures for Identifying Operators with Significant Market Power in Telecommunications Business B.E. 2557 (2014). According to these Notifications, the Office of the NBTC must prepare a report on analysis of the level of competition in the relevant markets and propose a list of operators with SMP in each relevant market for the NBTC's consideration. This will be used as a basis for outlining measures for the supervision of anti-competitive behaviors in telecommunications market in alignment with the above-mentioned Notification, and also for formulating a guideline to prevent the operators with SMP from abusing their market power to restrict or hinder free competition in the market.

The NBTC additionally issued the Notification Regarding Criteria and Procedure for Accounting Separation in Telecommunications Business as a tool to support the implementation of measures for the prevention of monopoly or unfair competition in telecommunications business. Under the Notification, the operators with SMP are required to undertake accounting separation for the NBTC's analysis. This aims to:

- Identify the anti-competitive behaviors such as predatory pricing, margin squeeze, etc.
- Identify the discriminatory behaviors such as cross subsidization, a case in which the operators with SMP set an overly high price in a market where they have powers and use the received profit for cross subsidization in another market where they are inferior to their rivals; And
- Be a basis for determining the cost-based wholesaling and retailing rates without excessive return/profit.

**8. Universal Basic Telecommunications and Social Services**

Telecommunications plays an important role in people communication and also in promoting capability development in other sectors such as manufacturing sector, trade and commerce sector as well as public and private service sectors. Therefore, the distribution of Universal Basic Telecommunications and Social Services will minimize the gap in communication and technology access which will improve the quality of life of the people in remote areas and bring about the equality and fairness in standard of living for all citizens both in the city and the remote areas. This will finally affects the national competitiveness level.

With all reasons mentioned above, the Telecommunications Master Plan B.E. 2555-2559 (2012-2016) aims to adopt measures to encourage operators in providing basic telecommunications services universally [11], promote the provision of basic telecommunications services to the underprivileged in accordance with the Universal Basic Telecommunications Services and Social Services Plan to ensure the access to quality telecommunications service at a reasonable tariff, to foster the provision of telecommunications service for social development and quality of life improvement as well as to improve the capability of telecommunications device manufacturing and telecommunications service for the disabled and the underprivileged.

In 2012, the NBTC has issued the NBTC's Notification Regarding Plan on Universal Basic Telecommunications Services and Social Services (B.E. 2555-2559) (2012-2016) aiming to promote and encourage nationwide distribution of wireline and wireless telecommunications network as well as to provide opportunity and develop capability in internet access for the underprivileged, the disabled, children, and senior citizens which will improve quality of life and the overall national competitiveness level. Subsequently, the NBTC has issued the NBTC's Notification Regarding the Criteria and Procedure for Revenue Collection to Fund the Provision of Universal Basic Telecommunications Services and Social Services which prescribes the criteria and procedure for revenue collection from telecommunications service licensees for contribution to the Broadcasting and Telecommunications Research and Development Fund for the Public Interest [12]. This is in order to secure funding for the implementation of the said Plan on Universal Basic Telecommunications Services and Social Services. The basic telecommunications services selected to be offered are telephone service and high speed internet service with no limitation of technology employed and the applications which include terminal equipment, software or other necessary peripherals. The goal is also include promotion and improvement of knowledge and skill which will benefit to the public for the appropriated and efficient access to the basic telecommunications services. Moreover, the licensees with their own network are required to annually contribute to the Fund at the amount of 3.75% per year of their net income from their telecommunications services as defined in the said notification.

It is expected that, after the successful implementation according to the Universal Basic Telecommunications and Social Services Plan (B.E.2012-2016), the personal telephone penetration rate will be at least 95% of Thai population and the high speed internet penetration rate will be at least 80% of Thai population. Also, there will be internet community center, internet service in school, internet service in community hospital as well as internet service center for target groups nationwide and telecommunications system for the disabled to access to information as others.

## 9. Current Spectrum Assignment for Telecommunication Services in Thailand

The utilization and the regulation of radio frequencies spectrum in telecommunication businesses is mandated by the Act on the Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services B.E. 2553 (2010) (the Organization Act) and the Telecommunications Business Act, B.E. 2544 (2001) [13].

Section 46 of the Organization Act states that a spectrum license for telecommunications business is the exclusive rights and is not transferable. The licensee who has been authorized to use spectrum shall carry out the services by himself or herself. Also, business management either in whole or in part shall not be rendered or permitted to other to act on his/her behalf.

In addition, Section 47 of the Organization Act stipulates that for any licensee who has been authorized to use spectrum for telecommunications services that has not carried out the business by using such spectrum within period specified by the NBTC, or by using such spectrum in other services not relating to its objectives, or fails to comply with the business operation conditions, or conducts any prohibitive acts as specified in Section 27 (11) or fails to comply with the provision of Section 46, the NBTC shall take action to rectify the situation or issue an order to revoke the spectrum license in whole or in part.

## V. CONCLUSION

In granting the spectrum license for telecommunications service, In granting the spectrum license for telecommunications service, NBTC, an independent telecom regulator, strives to achieve the regulatory balance composing of three eq strives to achieve the regulatory balance composing of three equally important principles in order to bring about the greatest benefits to the people and the country. These principles are (1) The most efficiency of spectrum assignment, (2) Free and fair competition, and (3) State benefits. In relation to spectrum management, national governance arrangements do differ in different countries, however it is a common practice that the remit of many independent communications regulators around the world includes responsibility for spectrum management. Spectrum management is typically taken to include the assignment of new licenses, operating under policy guidance from the national government. An independent regulator is also responsible for implementing market based approaches to spectrum assignment, which are appropriate when new spectrum licenses are being awarded, and in particularly where demand for licenses exceeds supply.

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# TEACHER PREPAREDNESS FOR EFFECTIVE CLASSROOM INSTRUCTION OF THE SECONDARY SCHOOL CHRISTIAN RELIGIOUS EDUCATION CURRICULUM IN KENYA

**Dr. Esther Kimosop**, lecturer in the Department of Curriculum, Instruction and Educational Management, Faculty of Education and Community Studies, Egerton University, P.O Box 536-20115, Egerton: KENYA.

**ABSTRACT**

*This paper focuses on teachers' preparedness to implement effective classroom instruction of Christian Religious Education curriculum in secondary schools in Kenya. The objective examined whether teachers: set instructional objectives and structured the content to be delivered. Descriptive survey research was carried out to establish this with forty five (45) form four C.R.E teachers in forty five (45) public secondary schools who were selected using simple random sampling. The instruments of the study were questionnaires, interviews and observation schedule (structured). The study established that 22 (48.6%) never accomplished the learning objectives. 30 (66.6%) write schemes of work but majority 25(55.5%) never refer to them often. The majority 39(86.7%) never wrote lesson plans. There is need for in-service and refresher courses to equip them with knowledge and skills to adopt modern ways of teaching. Therefore teachers are increasingly being expected to help support formal programme of education for they are agitators of classroom instructional activities.*

**KEY TERMS**

***Teacher preparedness, C.R.E curriculum, classroom instruction, secondary school, planning for instruction.***

## 1. INTRODUCTION

In Kenya the MOEST is responsible for formulating the curriculum and overseeing its implementation, whereas the classroom instruction is facilitated by the teacher who sees to it that it is implemented towards the right direction. The teaching is based on common phenomena of achieving the national goals of education. This was determined by the ability of the teacher to interpret, plan and implement the curriculum by following the procedures required by the profession to ensure that the instructional objectives are accomplished.

C.R.E like any other subject requires serious input by the teacher in terms of planning to teach to achieve instructional objectives. The Kenya National Examination Council (K.N.E.C) reports on the performance of C.R.E have been declining. This was attributed to poor coverage of the syllabus, poor approaches of teaching among others.

Walaba, (2008) indicates that the area of pedagogy has been a major area of concern in C.R.E which has been claimed to be lacking. Teachers are nearly being reduced to preachers, because they do not give adequate preparation that it deserves for orderly teaching. Academic performance in schools is attributed to adequate preparation by teachers, and teachers' laxity seriously hampers its achievement.

Brown et. al. (1994) stated that no matter how kind, amiable and well meaning a teacher may be, he or she cannot possibly succeed unless he/she has a thorough knowledge of the subject matter he/she is teaching and a good general knowledge. Teaching does not happen accidentally, and for it to be effective it needs thorough planning and preparation. Teaching is a complex endeavour, involving classroom management, lesson preparation and organization of teaching and learning activities , evaluation and feedback. Students' success in the classroom is largely based on effective classroom instruction and adequate preparation by teachers.

Rosenshine et.al (1995) indicated that planning should be the first thing a teacher should do when beginning to teach and meeting a group to teach for the first time, which is also an indicator to achieve educational goals.

Ofoegbu,(2004) further elaborated that the ineffectiveness of teachers in classroom interaction with the students could be responsible for the observed poor performance of students and the widely acclaimed fallen standards of education in Nigeria. This was linked to poor teachers' performance in terms of accomplishing the teaching tasks, poor teaching habits and scarce resources available for teachers.

The Sub-Saharan African (SSA) regional workshop for African teachers held on September, 2007 at Safari Park hotel, (Kenya) whose theme was "challenge of ensuring quality teaching in every classroom in Africa" was organized to help participating countries develop appropriate policies for managing the teaching force which in most countries constitutes the largest resource in the education system to help strengthen classroom practices.

In most cases, teachers are blamed for examination failures whereby parents and the general public attribute failure to teachers' laxity (Quality Assurance and Standards Circular No.1 2009). This was believed to be contributed by poor curriculum delivery and poor teachers' involvement on issues pertaining to classroom instruction resulting to the varied results in different schools which leaves one to wonder the disparities yet the instructions are done by same teachers who underwent same training programme.

Teachers need to prepare all the stages of the implementation of curriculum documents before they are actually used by the students through their assistance. It involves the preparation of the lessons by putting in place a scheme of work and a lesson plan having identified the instructional objectives, teaching aids and assessment tools, and use of the appropriate methods of teaching. It is expected that curriculum instruction will be based on these sound teaching principles which the teacher ought to follow for effective classroom instruction.

The subject's performance has been threatened by the belief that it is a booster subject pursued by average students academically so as to boost their grades hence lacks the seriousness it deserves from both teachers and students, where they assume that it can be passed even with less input.

Effective classroom instruction entails three main stages and the teacher is the pivotal figure who sees the implementation of these stages where each stage is confirmed by the performance of the other through proper classroom instruction as shown on **Fig.1**

(a) Preparation stage **(Planning)**
   (i) Identification of the content to be covered in the syllabus and breaking it down into topics.
   (ii) Identification of the objectives - both general and specific.
   (iii) Scheming the content.
   (iv) Lesson planning.

(b) Implementation stage **(Actual teaching)**

(i) Selection of appropriate teaching methodologies.

(ii) Use of teaching/learning materials.

(c) Evaluation stage **(Achievement of instructional objectives)**

(i) Assessment/evaluation measures used.

(ii) Feedback measures used.

Oketch and Asiachi, (1986) contend that teachers should take the following measures before beginning to teach;

1. Read the official syllabus description of the subject.
2. Selecting the broad content areas, which the subject teacher is to cover, this is planned in such a way that it fits the content description of the subject.
3. The teacher is to consider whether the amount of content will be achieved within the stipulated time.

The study points out that the learners equally with the teachers should know the content they are to learn with the guidance of the syllabus book which should be at their disposal.

Planning for instruction requires related documents and records for use in the instructional development process. The teacher needs the teaching documents which are the items any serious teacher must know to be able to develop and use them in instruction (Urevbu ,1985). The required documents to achieve this, is the use of the syllabus book that guides a teacher to plan for effective classroom instruction, where they should use it to identify the objectives, write the scheme of work and lesson plans.

In Kenya the syllabus contains national goals of education and they usually contain the teaching themes or topics, teaching methods /learning activities, resources for teaching and references. The C.R.E syllabus is usually developed by subject specialist panel composed of seasoned teachers, Ministry of Education, stake holders in education which include teachers and church leaders.

The syllabus indicates the level of usage, which should be accomplished at that particular level, the expectations are that, it should not spill to the next level, thus facilitating the formation of instructional process.

The syllabus has the following values:

1. It provides teachers with objectives of teaching the particular subject.
2. It provides some information on the themes to be taught which should be logically and concentrically developed.
3. It is a source of information on reference, and resource to be used in teaching.
4. It provides a teacher with the foundation of preparing schemes of work.
5. It provides a teacher with information on duration of teaching seasons.
6. It provides a teacher with information on time allocation.

It is mandatory that teachers should possess syllabus books to extract the content to be taught and to be guided by the objectives stipulated to be accomplished in it, it guides the teacher towards the right direction in teaching. The study established that teachers rarely referred to it often but always the text book was used for reference in their classroom instruction and most students had not seen a syllabus book.

The C.R.E syllabus derives its structure from the four main dimensions.

1. The Old Testament
2. The New Testament
3. The African Heritage
4. Contemporary Christian living

Content coverage plays a very important role in teaching/learning, because the learners will not be short of content in some areas, the teacher must clear the content in every class to avoid it spilling to the next classes. This requires the teacher to coordinate its teaching by planning classroom instruction well, however the study revealed that teachers never cleared the syllabus in time and content of particular classes spilled to the next class. This was attributed to poor planning.

According to Oberg, (1991) content consists of the subject matter which is used to achieve curriculum goals. He points out that content in the syllabus is thematic in nature and it has been put in an orderly manner such that if one theme is skipped then the learners may not be able to conceptualize the previous content learnt in relation to the present content learnt. Many educators have established that if content that ought to be learnt is incomplete then acquisition of curriculum goals will not be achieved. This will only be achieved if the teachers plan their lessons well. There exists a gap in teachers' preparation to realize effective classroom instruction, they determine quality education through classroom instruction which is measured by student learning achievements.

## 2. METHODOLOGY

Descriptive survey research design was used. Simple random sampling was used to identify the study population consisting of forty five (45) schools and forty five (45) form four C.R.E teachers. The use of questionnaires, interviews and observation schedule (structured) was used to obtain data from the forty five (45) form four C.R.E teachers from forty five (45) public secondary schools upon which it was analyzed and presented. Koul, (1992) observed that survey design is the only means through which views, opinions, attitudes and suggestion for improvement of educational practices and instruction can be collected. The design which is based on understanding of human behaviour, interpreting their thoughts, feelings and actions, allowed the study to explore the processes and meaning of events.

The data collected was analyzed using descriptive statistics to determine frequencies and percentages. These were presented using tables.

Being an exhaustive study of classroom instruction by teachers the study unraveled various processes of instruction by teachers in class by checking on how they prepared that instruction and by observing how they administered it.

The study monitored the interaction between the teachers and the learners in the process of teaching/learning respectively and hence able to interpret every event that took place. It deepened the researchers' perceptions and gave a clearer insight on how teachers implemented the curriculum by observing, getting opinions, and interpreting data.

## 3. RESULTS AND DISCUSSION

The study investigated teachers' instructional processes in their natural settings through observation by encouraging them to perform their habitual duties. This made the study to record unbiased information. **Table 1** shows responses on the achievement of instructional objectives. The findings showed that majority of the

teachers 25(55.6%) never stated the objectives before teaching and they taught right from the start of the lesson as confirmed by an interview before classroom instruction. And with those who had set up their objectives before classroom instruction majority 22 (48.9%) indicated that they did not evaluate the learning objectives because of lack of time. Majority of the teachers 22 (48.6%) never accomplished the learning objectives. The teachers further elaborated in an interview after classroom instruction that the learning objectives were not accomplished because majority 24 (53.3%) never planned to accomplish.

According to Twoli, (2006) the function of instructional objectives is that :

1. They provide a guideline for selecting the subject matter, learning activities and teaching/learning resources.
2. They provide direction for the teacher. A teacher is able to plan his/her teaching if they are clear about what they want their learners to achieve.
3. A clear statement of objectives provides a basis for the learners' assessment. It is easier to set questions in examinations or tests based on the instructional objectives.
4. When objectives are stated in behavioural terms, they make it easier for the teacher to judge the success or failure of the lesson.

**3.1: How the teacher should structure the content to be delivered.**

**3.1.1. Planning to teach.**

This means deliberate planning and organization of teaching /learning experiences in the light of psychological and pedagogical principle with a view to achieving specific goals. It is concerned with the way in which content is presented in instructional environment.

It takes into account the entry level of the learner, the age and the ability of the learners, active involvement of the teacher and active participation of the learners to accomplish the intended learning objectives, the following preparations are made after identifying the content and its objectives by teachers.

**3.1.2 Schemes of work**

A scheme of work refers to guidelines designed to make the teaching of a subject more manageable. It provides supporting information about planning and teaching the subject and form documentary evidence about course delivery. Schemes of work are likened to a road map of a journey. The scheme of work ensures that the syllabus is completed or covered within a given period of time. It helps teachers to provide continuity in the lessons and sequence in the learning in an orderly manner.

Schemes of work provide supporting information about planning and teaching the subject and form documentary evidence about course delivery which helps to guide subject delivery. Unplanned course delivery adds to workloads, and as planning tools, schemes of work can also be seen as way makers for course delivery by determining the prerequisites for moving (Grimmitt, 2000). Groenewegen, (1990) reiterates that the main factors to be considered while writing the schemes of work of C.R.E are; content derived from the syllabus book, objectives, teaching/learning activities and resources for teaching/learning.

The study established that 30(66.6%) of the teachers make schemes of work but majority 25( 55.5% ) never refer to them often. The summary is presented on **Table 2** and **Table 3**

By the end of the course or specified time a teacher can study the scheme of work to see what he/she taught well and what he/she did not teach well, what he/she covered and what he/she might have left out. This will help a teacher make adjustments in his/her instructional design and it facilitates lesson planning since they give a teacher ready instructional objectives, topics, sub topics, learning aids and references (Mukwa and Too, 2002).

### 3.1.3 Lesson planning

After scheming, another important aspect of teacher's preparation is lesson planning, the study established whether teachers planned their lessons as part of structuring the content to be presented. Kirisoi, (2008) elaborates by saying it challenges the teacher to select and use appropriate pedagogy activities that involves learners participation. He elaborates that it captures on who is to be taught, what is to be taught, how the content is to be involved in the learning process and how the teacher is to determine whether the learners have learned.

Kafu,(2003) and Twoli,(2006) stated that lesson planning gives teachers confidence in curriculum instructional processes. They argued that during planning, teachers selects the relevant content to the lesson to be taught and organizes it in a functional way to help achieve the instructional objectives.

The data established that majority of the teachers 31(69.0%) expressed that it was not necessary to do lesson plans and the remaining 14(31.1%) were not certain about making lesson plans. The majority 39(86.7%), seem to know the need of making lesson plans. However, they may not have taken the responsibility to do so. The summary is presented on **Table 4** and **Table 5**.

Lesson planning is the most critical part of a teacher's instructional activities. A lesson plan is a well prepared and systematically arranged programme, which acts as a form of reminder of what a teacher is going to teach and how he/she intends to teach it.

In the class observation schedule, the study established that teachers did not use lesson plans and did not have clear objectives to guide the lesson. The teachers did not have a sequence to follow while teaching and that the lessons taught did not merge that of the schemes of work.

The study established some of the basic and essential documents used when planning to teach and to support teaching/learning in various learning institutions. Most of them were available but were not utilized. The summary of the findings are shown on **Table 6**.

## 4. CONCLUSIONS AND RECOMMENDATIONS

### 4.1 CONCLUSIONS

The research paper found that;

1. Majority of the teachers were knowledgeable on objective writing and its usefulness however most of them did not set any objective while teaching, and majority did not evaluate the accomplishment of the knowledge learnt, this affected assessment and feedback.
2. The study revealed that most teachers never structured their teaching in terms of making schemes of work and lesson plans although having knowledge about it and its usefulness, many had old schemes of work, which were rarely used, and many never saw the need of making lesson plans, which they attributed that it

3. A scheme of work goes hand in hand with lesson plans, majority of the teachers used textbooks and not lesson notes and they encouraged students to make notes using them, making the students to reproduce same materials. It was established that the learners lacked the skill of summarizing.

### 4.2 Recommendations

Basing on the conclusions above, the following are some of the recommendations made:-

1. Teachers should always make sure that they prepare for their lessons and to deliver them using appropriate teaching strategies, and involve the learners in various activities during the lesson so as to enhance instructional skills that promote understanding and acquisition of knowledge.
2. When planning to teach the teacher needs to formulate instructional objectives so that the learner knows what is expected of them, this will encourage; better instruction, more efficient learning results, better evaluation and the students to be better self evaluators.
3. There is urgent need to increase in-service education activities to equip teachers with the latest skills and to grow professionally.
4. The planning and preparation of lessons should be made compulsory for teachers and the head teachers should be mandated to monitor.
5. A quality assurance mechanism should be enhanced to ensure that schools meet a high integrity on implementation of the curriculum through their supervisory roles and assessment. Hence will enable unearth the teachers' weaknesses to be tackled in time.

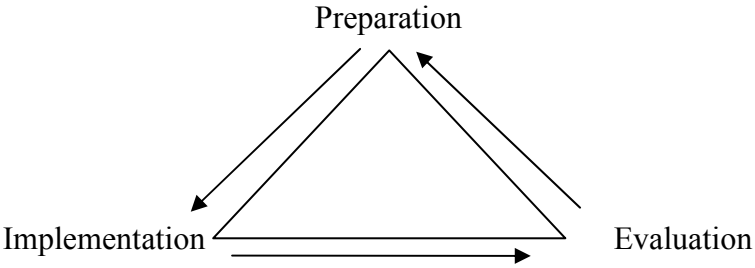


**Fig 1: Illustrating teaching/learning process**

**Table 1: Achievement of instructional objectives**

| STATEMENTS | RESPONSES | | | | | | TOTAL | |
|---|---|---|---|---|---|---|---|---|
| | **Often** (O) | | **Rarely**(R) | | **Never (N)** | | | |
| | Count | % | Count | % | Count | % | Count | % |
| (a).The teacher stated the objectives before teaching | 10 | 22.2% | 10 | 22.2% | 25 | 55.6% | 45 | 100% |
| (b).Planning to accomplish the objectives | 9 | 20.0% | 12 | 26.7% | 24 | 53.3% | 45 | 100% |
| (c).Whether the objectives were accomplished | 11 | 24.4% | 12 | 26.7% | 22 | 48.9% | 45 | 100% |
| (d).The teacher evaluates the | 13 | 28.9% | 10 | 22.2% | 22 | 48.9% | 45 | 100% |

## Table 2: Frequency of writing schemes of work by teachers

| Frequency of writing schemes of work | | |
|---|---|---|
| | Count | % |
| Often | 30 | 66.6% |
| Sometimes | 9 | 20.0% |
| Rarely | 6 | 13.3% |
| **Total count** | 45 | 100% |

## Table 3: Frequency in reference to the scheme of work by teachers

| How often they refer to the scheme of work. | Teacher responses | |
|---|---|---|
| | Count | % |
| Never | 25 | 55.5% |
| Sometimes | 8 | 17.7% |
| Rarely | 6 | 13.3% |
| Often | 6 | 13.3% |
| **Total count** | 45 | 100% |

## Table 4: Necessity of writing lesson plans by teachers

| Whether necessary to write lesson plans | Teacher responses | |
|---|---|---|
| | Count | % |
| Necessary | 5 | 11.1% |
| Not Necessary | 31 | 69.0% |
| Sometimes | 9 | 20.0% |
| **Total count** | 45 | 100% |

## Table 5: Reasons for writing lesson plans by teachers

| Reasons for writing lesson plans | Teacher responses | |
|---|---|---|
| | Count | % |
| Expected to plan by my profession | 1 | 2.2% |
| Helps to teach better | 2 | 4.4% |
| Helps to achieve learning objectives | 1 | 2.2% |
| Helps to sequence the teaching | 2 | 4.4% |
| All the above | 39 | 86.7% |
| **Total count** | 45 | 100.0% |

**Table 6: The availability and use of basic and essential documents in schools.**

| S/N | Document | Whether available | | Whether used | |
|---|---|---|---|---|---|
| | | Not available | Available | Used | Never Used |
| 1 | Schemes | 15 | 30 | 5 | 25 |
| 2 | Records of work | 15 | 30 | 10 | 20 |
| 3 | Lesson notes | 20 | 25 | 10 | 15 |
| 4 | Lesson plan | 40 | 5 | 0 | 5 |
| 5 | Progress records | 25 | 20 | 8 | 12 |
| 6 | K.N.E.C reports | - | 45 | - | 45 |
| 7 | C.R.E exam analysis | 10 | 35 | 5 | 30 |
| 8 | Syllabus books | - | 45 | 16 | 29 |

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# Rehabilitation and Reintegration as a Key Activity of Post- War Peacebuilding in Sri Lanka

**Osantha N. Thalpawila**
Senior Lecturer, Department of Economics, University of Kelaniya, Sri Lanka

**Abstract**
*More than ten thousand former combatants who were fighting on behalf of the LTTE surrendered to the government forces during the last stages of 26 years of civil war in Sri Lanka. The government of Sri Lanka conducted a formal programme to reintegrate them into the society. The aim of this programme was to rehabilitate them by transforming their minds from war to peace. The aim of this paper is to look into the successful of the government's project as a partner of building long lasting peace in post war era in the country. To fulfil this task this paper uses primary and secondary data appropriately.*
*The UN theory and other theories of post-conflict peacebuilding focused on the rehabilitation and reintegration of former combatants under the DDR process. Although, the programme illustrate a significant progress of the beneficiaries changing their minds towards peace, some problems have been affected related to their livelihood matters and civil life.*

Key words*: rehabilitation, reintegration, peacebuilding, ex-LTTE cadres, vocational training*

## 1. Introduction:

The 26 years of protracted civil war in Sri Lanka ended in 2009 and was defeated the LTTE the separatist militant movement by the government forces. The government of Sri Lanka (GoSL) commenced the peacebuilding and post war reconstruction in the post war country since then. Among the peacebuilding process rehabilitation and reconstruction of former illegal militant groups was a key activity in order to achieve a long lasting peace and confirm the security of a war affected country.

The case in Sri Lanka pointed out that more than ten thousand former LTTE combatants surrendered to the government forces during the last stages of the war. Among those combatants were men, women and children who were fighting on behalf the LTTE over several years. Most of them were experts at using arms and had been brainwashed by the LTTE. Therefore, it is an important undertaking to rehabilitate them by transforming their minds from war to peace. On the one hand, it is very important to reintegrate those combatants to ensure the future security of the country and on the other hand, as individuals it will help to secure their future in civil society as productive and useful citizens. Rehabilitation and reintegration of those former combatants will help to secure a better life for them as well as safeguard the security of the country. The UN documents on post conflict peacebuildingand the other scholarly work of post-conflict peacebuilding focused on the rehabilitation and reintegration of former combatants under the DDR process, which stands for disarmament, demobilization, and reintegration. This would demilitarise the paramilitary groups and other illegal militant groups that took part in the civil war. The government could then reduce the numbers of its armed forces personnel and lower the defence expenditure. Reintegrate process involves with former

aims to fulfil some objectives in connection with former combatants such as facilitating to provide livelihood and economic opportunities, developing family and community relations, minimizing psychological impacts. In that sense reintegration is a long term process which assimilate of ex-combatants to civilian life (Knight, 2010). The World Bank stresses that the reintegration of child soldiers should be consisted of three important components such as family reunification, psychological support and education, and economic providing economic opportunity (Ozedem,2007). Even though the theory stresses the process of DDR, Sri Lanka does not apply the entire concept of DDR, since the way the war ended in Sri Lanka did not create a situation requiring disarmament and demobilization.[1] Therefore, under the rehabilitation and reintegration sector of the post war peacebuilding process, the government focused on the task of rehabilitation of the ex-LTTE cadres and their reintegration into society since the GoSL assumes it to be an important activity required to build stable peace and reconciliation in the country in future.

**2. The DDR process in Asian conflict affected countries**

The literature of post-war peacebuilding reveals a number of examples of rehabilitation and reintegration of ex-militant combatants from civil war affected countries. In most cases the peace agreements are embedded with the strategies on rehabilitation and reintegration of ex-combatants as a preventive method against future violations and as a method of sharing the peace dividend. The process of DDR served to fulfil this task, which was proposed in the theory of post-conflict peacebuilding. For example, Aceh is a province of Indonesia, which suffered thirty years of secessionist armed conflict between the government forces and the militants of the 'Free Aceh movement'. This long running civil war resulted in 15,000 deaths (Askandar,2007). A peace accord between the Government of Indonesia and the Free Aceh Movement (GAM)was eventually concluded in 2005 to bring an end to the violence and establish long lasting peace.[2]The peace agreement had taken into consideration the issue of the rehabilitation and reintegration of ex-GAM activists under section 3.2 'reintegration into society' as a responsibility of the Indonesian government.[3]Article 3.2.3 mentioned that the government of Indonesia will provide all facilities to assist the GAM activists to reintegrate them into civil society and to provide economic support. Article 4.2 says that GAM will undertake to demobilize all of its combatants who had taken part in militant activities. The conflict affected countries in the African region such as Angola, Mozambique, Namibia, South Africa, Zimbabwe, Uganda and Sierra Leone initiated rehabilitation and reintegration programmes in their post-war environments in the 1990s. Several studies reveal that the programmes for the ex-combatants and the child soldiers of warring parties to rehabilitate and reintegrate into civil society are conducted with the help of the UN and foreign governments. Those programmes were carried out under the process of DDR largely and beneficiaries could participate in rehabilitation courses consisting of psychosocial counselling, health screening, provision of food and other basic necessities, education and skills training (Dzinesa, 2007; Williams, 2006; Ball 1997). However, some programmes revealed ineffective outcomes for the beneficiaries due to the lack of financial support, low rate of providing job opportunities, and inadequate concern for female ex-combatants (Ball,1997; Dzinesa,2007; Knight,2010).

[1] The study focuses on the militants of the LTTE who surrendered to the government forces at the end of the war. The other LTTE militants were killed in the final stages of the war along with their leaders.

### 3. Rehabilitation of Ex-LTTE cadres

As mentioned earlier, the official reports show that 11,664 ex-combatants surrendered to the military forces and the government felt a strong commitment to reintegrate them with civilian society after a suitable rehabilitation programme. The GoSL's established institution, "The Bureau of the Commissioner-General of Rehabilitation" carried out the rehabilitation programme for 11,664 ex–LTTE cadres in six rehabilitation centres in the Northern Province. As mentioned in above the LTTE cadres were highly brainwashed by the organization and alienated from the civil society. Therefore, it proved to be an important and challenging task to rehabilitate the ex-cadres in order to reintegrate them into the society. Those rehabilitation centres are commonly referred to as 'Protection, Accommodation and Rehabilitation Centres' (PARC). The rehabilitation programmes were conducted in four rehabilitation centres in Vavuniya and Polonaruwa districts.[4]Several United Nations and Humanitarian organizations, notably the IOM and HALO Trust, have been assisting the Sri Lankan government in the task of rehabilitation of ex-combatants since 2009.The rehabilitation programme was designed according to the model of the International Centre for Political Violence and Terrorism Research in Singapore (Dharmawardhane,2014). The extensive residential programme was consisted of six modules as (i) educational, (ii)vocational, (iii) psychological and creative therapies, (iv) social cultural and family (v) spiritual and religious (vi) recreational and community rehabilitation and named as the "6+1 model" (Hettiarachchi,2012:106). The modules of the programme were focused on the following aspects. (1) The first programme was counselling to implant spiritual, cultural and religious values in the ex–cadres. Daily religious observances, meditation and spiritual development programmes, including celebration of religious festivals were organised at this stage. Special tours were organised to visit religious places (From Conflict to Stability- Northern Province,2012). (2) The ex–combatants who were students were directed to complete their formal education. Education facilities were provided to them by organizing a number of classes up to G.C.E advanced level. (3) Training programmes were organised in vocational training centres to enhance their future livelihood prospects. There were 46 different vocational training courses organised under the modules for eligible men and women in the rehabilitation centres.[5] (4) The programme was designed to mould their thinking so as to get them to appreciate the need for reintegration with their families and society. Several counselling workshops were organised on marital, premarital relationships and family planning.(5) The programme on physiological and curative therapies aimed at individuals and groups. Several cultural programmes in theatre and art work were organized. (6) The programmes were to promote sports and extracurricular activities of the ex-cadres (From Conflict to stability-Northern province, 2012). At present, 11,600 persons have been reintegrated into society after having successfully completed their rehabilitation in the centres (Selvakumar,2013).In order to supportthe reintegrated person's livelihood matters, the government provided facilities for rehabilitated cadres to apply for loans from the "State Banks" to finance their self-employment projects. According to that States Banks provided Rs.250,000 as loans at mere 4% annual interest to rehabilitated ex-cadres (Selvakumar,2013).After submitting their project proposals the rehabilitated ex-combatants could apply for this loan. The Commissioner-General of Rehabilitation pointed out that the President had allocated Rs.525 million to assist the rehabilitated cadres in their self-employment ventures

[4]Rehabilitation centers in Vavuniya district – Poonthottam and Maruthamadu, and Polonnaruwa district - Senapura and Kandakadu.

[5]The subjects available to the men for vocational training are plumbing, aluminium work, electrical wiring, leather work, tailoring, carpentry, masonry, welding, driving, heavy machinery operation, auto repairs, coconut and mushroom cultivation, chemical

(Wijayapala,2013). In addition to the loan facility, the rehabilitation bureau is exploring ways to provide them with employment opportunities overseas.[6]

The Secretary to the Presidential Task Force (PTF) said that among the ex-combatants who surrendered to the government (see Table 1 for details), 118 persons involved in serious crimes were charged and all others were given amnesty by the government.[7] Further, he mentioned that the Army helped the ex-combatants who were given amnesty by the government to establish self-employment projects, after the rehabilitation programmes.

**Table 4.7 Details of the surrendered ex-LTTE combatants**

| Children(12-18yrs) | Numbers |
|---|---|
| Boys | 363 |
| Girls | 231 |
| Adults | |
| Men | 9,037 |
| Women | 2,033 |
| Grand Total | 11,664 |

Source: "From Conflict to Stability – Northern Province" (2012) p. 20

There were 594 child combatants, including 231 girls who voluntarily surrendered to the security forces. Out of this, 273 children wished to continue with their formal education. The rest underwent proper vocational training programmes at the technical college in Vavuniya under the Vocational Training Authority.[8]

Further, all ex-LTTE child combatants had followed a special English language course and also Girl Guide and Boy Scout programmes as auxiliary programmes.[9] The rehabilitated child combatants were handed over to their parents as normal persons, expected to lead normal lives in the country in the future.

**4. Rehabilitation and reintegration**

As mentioned above, the LTTE cadres were highly brainwashed by their organization and alienated from the civil society. Therefore, it is an important and challenging task to re-educate and rehabilitate the ex-cadres in order to reintegrate them into the society. According to the findings of this study, the government was able to fulfil that task to a certain extent.

[6]"Rehabilitation of ex-LTTE cadres nearing completion," http://www.defence.gov.lk
[7]Interview with Mr. S.D.Divarathna, the Secretary to the PTF, 7 February 2014 at Colombo.

According to Hettiarachchi (2012) the rehabilitation programme in Sri Lanka can be characterized as a globally developed rehabilitation programme.

> "Global rehabilitation programmes can be characterized as developed, developing and defunct programmes. The most developed programmes are operated in Saudi Arabia, Singapore, Malaysia, and Sri Lanka. The developing programmes are in Iraq, Afghanistan, Pakistan and Colombia. Defunct programmes are in Egypt, Yemen, and Libya." (Hettiarachchi,2012: 106) [10]

The rehabilitation programme conducted in Sri Lanka can be seen as quite reliable and successful in its content and process. It consisted of six modes of rehabilitation and community engagements. How did this rehabilitation programme benefit the ex-LTTE cadres? Was the government able to achieve its goal successfully? The following analysis will provide the answers to these questions.

As mentioned earlier, rehabilitation is about changing the thinking and behaviour of offenders. The beneficiaries appear to be satisfied about the programme and they have changed their attitudes. A beneficiary who was 40 years old expressed his feelings at a press interview as follows:

> "We know the pain of war. We will not allow our children to experience the same pain. If possible, we will work towards peace and unity."[11]

A rehabilitated beneficiary of around 33 years who was with the LTTE for five years expressed his views briefly:

> "I regret what happened in the past. Now I have understood well what peace is. I am now involved in my farming activities and want to look after my family well. My future ambition is to live in the society peacefully."[12]

These feelings of the rehabilitated persons show that their minds are changed and they are now looking to lead peaceful lives even though they fought for the LTTE a few years ago using arms and ammunitions against the Sri Lankan security forces. Furthermore, during the period of PARC, the authorities granted facilities to some young persons who were committed to their education to continue it, with the help of the Education Ministry. The Bureau, together with the Education department, conducted an accelerated catch up education programme for those who opted to appear in national exams. Two centres were established for this purpose, for males and females (Hapuarachchi,2011).Many students who sat for the national examinations passed with flying colours, and were selected for higher education. For example Out of 361 students who sat for the Advanced level examinations, 222 qualified to enter the University, and out of this number 12 will join the Medical Faculty, one will be entering the Engineering Faculty and about 30 will be joining the Commerce and Arts fields in the Universities (Hapuarachchi,2011).

So, taking steps to prepare those students to sit for the advanced level examinations is a worthy deed. Those students who were qualified to pursue higher studies were enrolled to follow their chosen courses in the Universities (Wejethilaka, 2014). In the ordinary level examinations, out of 166 students, 91 students were

[10] *Ibid*., p.106

qualified to proceed to Advanced Level (Wejethilake,2014). As mentioned above the rest of the rehabilitated cadres went on to undergo vocational trainings, and later completed their courses successfully. The aim of these vocational trainings was to reintegrate those persons into the society. All these trainees were encouraged to start self-employment projects, according to their trainings. A vocational trainee expressed his views as follows:

> "I surrendered to the security forces on 16th May, 2009 in Omanthai. I was later transferred to the 'Boossa' camp. From there I was sent to the rehabilitation centre where I underwent the vocational training programme, specializing in masonry. I am still single, and once I go back home to my mother, I plan to make use of the skills I have learnt and developed during my rehabilitation programme. I am going home to meet my family after being in various detention centres for three years and eight months. I am anxiously waiting to finally lead a normal life in a peaceful Sri Lanka." (Nathaniel,2013)

Even though these people underwent vocational training, finding a job in the Northern Province proved quite a difficult task in the post-war situation, especially for rehabilitated cadres. It is noteworthy and so must be mentioned here that the government was ready to assist the trainees who were willing to establish their own self-employment projects by providing financial assistance through bank loans. According to the government loan scheme 1,773 ex-cadres were given loans and many more applications were being evaluated. (Wejethilake,2014). The percentage of rehabilitated ex-cadres who received the bank loan is 18%. However, in the technical context this did not prove to be a successful exercise. Those people who applied for loans had to face many difficulties in settling the loan. Therefore, the other trainees who were aware of this problem were discouraged from applying for loans. This is why the number of applicants for loans was so small.

The rehabilitated persons face some problems and difficulties in connection with their livelihood matters. It is worth to mention here unemployment is a major issue for these rehabilitated persons. Disabled people particularly, who were injured during the war, faced a lot of difficulties in finding a job. Finding employment is a very difficult proposition for ex-LTTE cadres in Northern Sri Lanka, due to two reasons. One is conflict related disabilities suffered by these ex-cadres and the other is the persistent stigma attached to former LTTE cadres. According to statistics, around 10,000 to 20,000 people out of the total population of the Northern Province are affected by war related disabilities.[13] A majority of them are reported to be former LTTE cadres. In Northern province Sri Lanka, some disabled persons were engaged in their daily routine as usual, but many people do not like to give work to persons with certain disabilities as they are not efficient.[14] The second issue affects the ex-LTTE cadres directly, because some people dislike interacting with them due to their history. A villager in the Northern province Sri Lanka said that some people dislike to give them jobs in their fields or business since the people do not still trust them.

However, some ex-LTTE cadres are also bothered about their history. The above two reasons affect their employment prospects.

However, the Commissioner-General of Rehabilitation points out that they are giving attention to monitoring their livelihoods and exploring employment opportunities.

> "We have designed a mechanism to monitor the progress of those who have reintegrated into the society. We plan to monitor them post rehabilitation, to restore their livelihoods and explore employment opportunities. This is to ensure that once they are released, they lead normal lives as useful citizens and make their contribution towards the development of the country" (Sriyananda, 2012).

The Commissioner General of the Rehabilitation Bureau said that besides providing bank loans for projects the government also sought to provide employment opportunities in foreign countries to the rehabilitated persons. So far, the Bureau has got a positive reply from a construction company in Singapore expressing their interest in recruiting 40 rehabilitees who have received vocational training (Wejethilake,2014). According to the Commissioner-General, they have planned another project to give 'three wheelers' to the rehabilitated persons without down payments, so they can re-pay the instalments while earning. (Sriyananda,2012) Further, the government has recruited a large number of reintegrated beneficiaries to the 'civil defence forces' and those rehabilitees will be assigned to various development and agricultural projects in the country. (Nathaniel,2013). For example some rehabilitated ex LTTE cadres were participated to renovate some irrigation projects in Kilinochchi districts. The Rehabilitation Bureau has made an arrangement to train and develop 50 beneficiaries into professional counsellors with a plan to recruit them into the social services sector.(Hapuarachchi, 2011).

Although an economic foundation is a vital necessity for re-integrated cadres, social acceptance too plays a remarkable role in re-integrating rehabilitated persons into the civil society. To address that task during the period of rehabilitation the government arranged friendship tours in order to build harmony with other communities. In particular, this programme aimed to establish cordial relationships with the Sinhalese in the South. The "Friendship Tour from North to South" was organised from 6$^{th}$to 9$^{th}$June, 2014.[15] This friendship tour aimed to engage the rehabilitees and get them to interact with civil society and to experience some contact with different communities to increase mutual understanding. During this tour, rehabilitees joined with the Sinhalese in several mutual activities such as games, religious activities and also they visited important places during the tour. It is very important to organize programmes such as these to integrate the ex-cadres into the society. Further, the Rehabilitation Bureau conducted an art exhibition known as, "Reflection of Transformation through Art" in April, 2011 (Hapuarachchi, 2011). This can be considered as another valuable opportunity for rehabilitees to express their feelings. The rehabilitees are encouraged to re-integrate into the social milieu in many ways. The Bureau granted approval to the ex-combatants to get married during the rehabilitation period. For instance, 53 couples got married and all their ceremonies were organised by rehabilitation centres according to the religious customs of the community (Hapuarachchi, 2011). They were also given a house and a plot of land for each family for cultivation in the camp premises, during the rehabilitation period. The Commissioner-General of Rehabilitation said that they looked at many aspects to provide them facilities for meditation, sports, educational and vocational trainings during the period of rehabilitation. He was interviewed by a leading newspaper in Sri Lanka and mentioned that,

> "While educating them on theoretical aspects, they will be motivated to mingle with society, to be kind to people and respect and accommodate the ideas of other people. We held a special counselling programme for them with a view to changing their destructive ideology and mind-set which they had

acquired due to being brainwashed by the LTTE. Instead of taking revenge, we taught them to respect the people and to co-exist with them peacefully." (Sriyananda, 2012)

In that sense the government's perspectives on rehabilitation of ex-LTTE cadres was good because it helped to facilitate their reintegration into the civil society. The most important matter in this connection was the government's decision to grant amnesty to these rehabilitees. In 2009, a Presidential Amnesty was granted to the surrendered LTTE cadres who were later rehabilitated. The Director-General for Rehabilitation pointed out that only five or six complaints had been received so far against the rehabilitated cadres. They were all minor personal matters often found in any society(Selvakumar, 2012). In 2012 the US Ambassador to Sri Lanka stressed that the government of Sri Lanka had made good progress in the rehabilitation of ex-LTTE combatants.[16] This is a very good testament to the success of the rehabilitation programme carried out for the former LTTE cadres.

**5. Conclusion**

The process of rehabilitation of ex-LTTE cadres is still continuing. It is clear that consideration should be given to the livelihood of rehabilitated ex-LTTE cadres, because they need sustained support to re-build their lives. The theory of post-conflict peacebuilding addresses the issue of rehabilitation and reintegration of ex-combatants as a necessary reform required by the security sector, as that would minimise future threats and relieve society from a fear of future war. Although the government did not follow a comprehensive process of DDR as proposed in the theory, it had made the effort to rehabilitate the surrendered ex-LTTE child soldiers and combatants in terms of transforming them from an aggressive society into a peaceful society. Although, there are still some issues regarding their livelihood matters and some negative perceptions by society, the government process can be seen as a valuable and fruitful one to the beneficiaries as it helps to divert their minds from violence to peace.

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