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Hydrogeochemical distribution and characteristics of groundwater in Weligama area – in Southern Sri Lanka

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ABSTRACT

Groundwater table behavior and physico-chemical properties of the aquifer system in Weligama bay area were studied selecting 43 dug wells distributed over an approximately 15 km^2 area. Weligama is located in 80^{0}22'Lat and, 5^0 97 long; main river basin of the area is Polwattumodara Ganga. Continuous monitoring conducted from May to November 2005 pertaining to groundwater levels, Electrical conductivity, total dissolved solids and salinity helped to prepare hydrogeological map and hydrogeochemical map of the area using the GIS package MAPINFO. Most of the dug wells distributed in the area are shallow and 3-5 m in depth and 0.5- 1.5 m diameter. According to the results of the chemical analysis in groundwater, distribution maps of Na+, K+, Mg^{2+} and Ca^{2+} ions in the unconfined aquifer was plotted. The maps indicate distribution of the major ions in the groundwater associate with aquifer characteristics. The Mg^{2+}: Ca^{2+} ratio of the groundwater various in between 0.5- 0.7 in the coastal line where the calcareous sandstone is dominant. The Mg^{2+}: Ca^{2+} ratio between 0.7- 0.9 in the western region where groundwater is distribute in the hard rock. The rest of the area Mg^{2+}: Ca^{2+} ration is more than 0.9 where groundwater available in the alluvium aquifer.

Key words: Electrical conductivity, aquifer, alluvium, hard rock

INTRODUCTION

According to the world water budget 97.2% of water in the hydrosphere is brackish in oceans, and almost 2.15% of the left out is tied up as north and south glaciers, leaving relatively little portion as fresh water sources located in surface or subsurface reservoirs. Groundwater resource is the largest reservoir of usable water recourse available in the hydrological cycle, which consists only 0.9% of the fresh water reserve.

Even rainwater on arrival dissolves chemicals of various kinds, particularly in industrialized areas with substantial air pollution. Once atmospheric

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precipitation reaches the ground, it reacts with soil, rock, and organic debris, dissolving more chemicals naturally, leaving aside the pollutants generated by human activities. Streams, rivers, lakes have historically been used as disposal sites for untreated wastewater and sewage, which makes the surface waters unsuitable for drinking purposes without proper cleaning.

Rocks and soils through which groundwater passes provide a natural filter for the removal of many undesirable contaminants and can be of great benefit in water purification. Indeed, the development of groundwater for drinking water supplies over the past few decades has been instrumental in decreasing the incidence of serious water borne diarrhoea diseases in developing countries and as a result major benefit in improving public health is achieved. Nevertheless the quality of groundwater cannot always be guaranteed due to geo chemical reactions in the host aquifers can lead to the natural build up of trace elements derived from the rocks and soils which can be harmful if presents in sufficiently high quantities.

Groundwater quality may be described in different ways but one of the most important aspects is the assessment of natural groundwater quality with the balance of ions. Therefore the groundwater monitoring and quality assessment are important aspects for its utilization for human consumption.

The objectives of the present study are to identify the hydrogeochemical distribution in the shallow groundwater aquifer in Weligama bay area, Southern Sri Lanka. Dissolved chemicals in shallow groundwater and understand their distribution pattern along with the geological information that may be applied to the analysis of water-quality characteristics of surface and shallow groundwater:

Area of Investigation

Topography

The Weligama area is located in 80^0 22' latitude, and 5^0 97' longitudes, in the southern coastal belt of Sri Lanka (Figure 1). The southern part of the study area forms extremely flat coastal plain but south western coastal region is slightly high, reaching a maximum elevation of about 10 m above mean sea level. Generally, mean sea level of the central region of the area is between 1 to 5 m. Main river basin of the area is River Polwathumodara

Ganga. It flows through the division with a meandering, of about 160ha land extent. Delta of the Polwathumodara ganga is very large and tidal sea water can easily be intruded through the river. During the Tsunami disaster sea water wave flowed more than 2 km upstream through the Polwathumodara ganga.

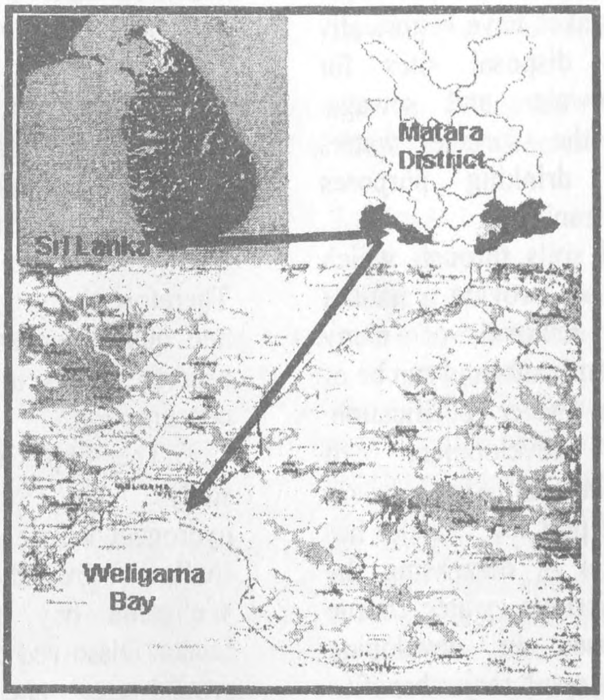


Figure 1.Study area in Weligama

Weligama town is the largest urban city in the study area, which is located 146km away from Colombo and it's in southern margin of Indian Ocean. This area falls within the WL_4 agro ecological region which is defined as an area where 75% expectancy of the annual rainfall exceeding 2400 mm. Annual rainfall of the area is between 1875 mm-2500 mm. In Annual mean temperature of the area is $25C^0$ and relative humidity is 75%-80%. Rains come mainly from southwest monsoon and an as inter monsoon rains during the intermonsoon periods. According to the topography the area is a flat low land near the coastal zone and maximum elevation of the area around 25m from MSL.

A part the population in Weligama urban council area and suburb meets their drinking water needs through the main water distribution system from Hallala (National water Supply and Drainage Board), but most of the households use shallow groundwater from open dug wells for drinking and domestic activities.

Geology and Hydrogeology of the area

Dominant rocks of the Weligama area are Precambrian metamorphic hardrock covered by Quaternary sedimentary deposits. Basement consists with Precrembrian rocks of the highland complex and consists of granite sillimanits with-biotite gneiss. Topsoil of the area mainly consists of sandy clay. The top unconfined alluvium aquifer is distributed in the river basin area and in the coastal line. Water bearing sand in top of the section is more often fine and lower section usually has coarse sand with small portion of gravel. In general , the aquifer consists of calcareous sand and along the river basin aquifer consists of sandstone. Recharge of the aquifer takes place mainly from precipitation in northern region of the catchments area. The top quaternary sandy aquifer and the surface soils of the coastal margin of Weligama bay area is very permeable. Here, the hydro geological conditions are very favorable for salt-water intrusion. Therefore, along the coastal belt, alluvial and coastal sand deposits dominate and form higher-yielding local aquifer systems.

MATERIALS AND METHODS

For the study, control-monitoring network of 43 dug wells distributed in Weligama Pradesiya Shaba division is selected. Locations of the dug wells were identified with a *GPS*. Continuous monitoring of the water levels in the dug wells was conducted and the water quality with respect to Electrical Conductivity (EC), Total Dissolved Solids (TDS) and salinity were measured using portable EC/pH meters at three to four week intervals. In order to identify hydrogeological features in the unconfined sandy/ sandstone aquifer the water levels of the monitoring dug wells were measured. *GIS* package *MAPINFO* was used to plot the hydrogeological and hydrogeochemical maps.

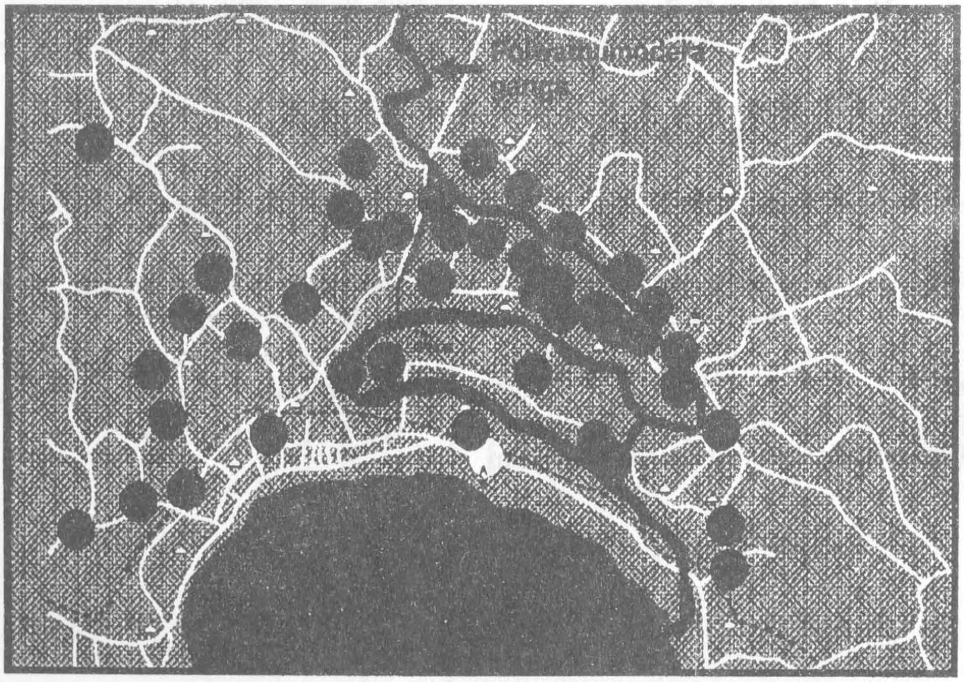


Fig. 2 : Groundwater Monitoring network map in Weligama

Sampling procedure: 25 wells were selected for water sampling from the network of 43 dug wells. 200ml. of settled unfiltered water samples was collected for the determination of major cations. Atomic Absorption Spectrometer was used to determine $Ca^{2}+$, $Mg^{2}+$, Na+, K+ ions.

Classification of water bearing formation according to the chemical analysis

For water flowing through Calcareous formations the Mg^{2+}/Ca^{2+} ratio is normally in the range between 0.5-0.7. The range 0.7-0.9 is commonly associated with groundwater available in the hard rocks (Table 1). Ratios exceeding 0.9 are sometimes found in fresh groundwater from Sandy alluvium formations. More often they indicate the admixture of sea water or brine. In brackish waters an increase of this ratio along the flow path may be caused by the precipitation of calcium carbonate or calcium sulfate, under high concentration of Ca ions.

Table 1 Groundwater Identification based on the ionic compositions. (Mandel, 1981)

Ratio or order	Range	Identification
Mg^{2+}/Ca^{2+}	0.5- 0.7	Calcareous formations
	0.7- 0.9	Hard rock
	> 0.9	Alluvium
Na^{+}/K^{+}	Around 47	Sea water
	< 10	Fresh water
$Ca^{2+} > Mg^{2+} > Na^{+}$		carbonate water
$Na^{+} > Mg^{2+} > Ca^{2+}$		Chloridic water

RESULTS AND DISCUSSION

Well characteristics

Most of the monitoring dug wells distributed in the area are shallow and are in the range of 1-7 meter in depth. However, more than 50% of the total depths of the dug wells are in the range of 3-4 meters. Wells which are sandwiched in between the coastal line and Polwathumodera ganga are very shallow and they are in range of 1-3 m in depth. The diameter of most of the wells are in the range of 1-1.5 meter.

Hydrogeological characteristics

Groundwater level near to coastal area lies closer to the ground surface and in between 0-0.99m (Figure 3). Groundwater level has been slightly increased in north-eastern and north-western regions. Recharge areas of the study area are north-eastern and North-Western region and discharge area indicate in the costal area. Hydraulic gradient of the groundwater in central and western section of the study area is changing from 0.002-0.0007. But hydraulic gradient of the western area is higher than central region. Due to low hydraulic gradient in the central region groundwater flow from land side is low and sea water intrusion easily forced in to the aquifer and equilibrium can damage very easily. According to the hydro isograph, discharge area of the study area lies with the the Pollathomodara ganga.

According to the data received during the period total dissolved solids levels are not changing in the study area. In coastal areas, TDS values are high due to intrusion of sea water with the tsunami wave (Figure 4). Here, a very favorable sandy fresh water aquifer lens was available and it's now converted to be saline due to the tsunami waves. Availability of fresh water in this aquifer system depends on the thickness and the hydrogeological characteristics of the aquifer.

Hydrogeological, geological, morphological, and climatic information and chemical analyses helped to reconstruct the path of geochemical distribution in shallow groundwater. Sequence of processes through which water acquired its chemical composition was evident and this process is to be interpreted with reference to geohydrological and hydrogeological data

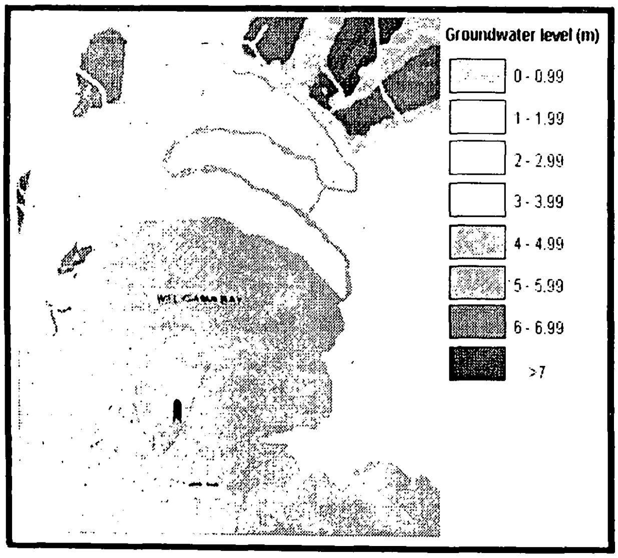


Fig. 3. : Groundwater contour map in May to October 2005

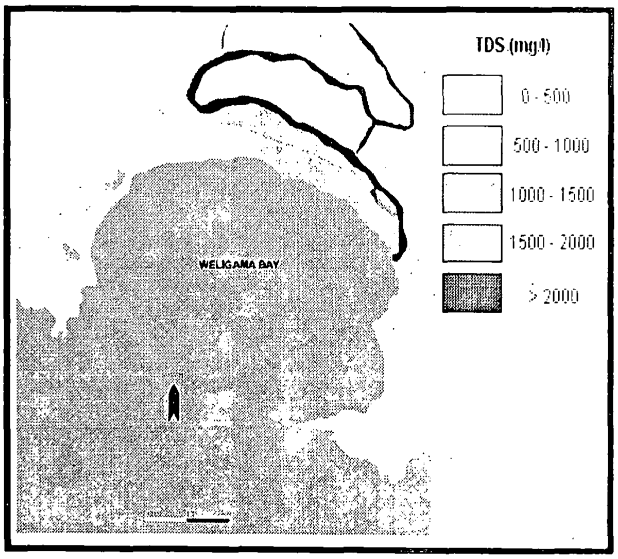


Fig. 4.: Total Dissolved solid distribution in groundwater in October 2005

Ca concentration in the groundwater

A calcium concentration in the groundwater is high in Weligama area (Figure 5). Along the coastal region and in the river basin area, unconfined aquifer consists with calcite sand stone which is very permeable. Observations of the dug wells constructed in the area According to the hydrogeological characteristics of the region main discharge area is associated with the Polwathumodara ganga region, due to which Ca dissolves in the groundwater and contribute to the aquifer

Mg concentration in central region of the area indicates high values (Figure 6). Mg values are high in the river basin area due to availability of calcite sand stone. But in western region the Mg concentration indicates low values compare to the central region, where metamorphic hard rock is dominant.

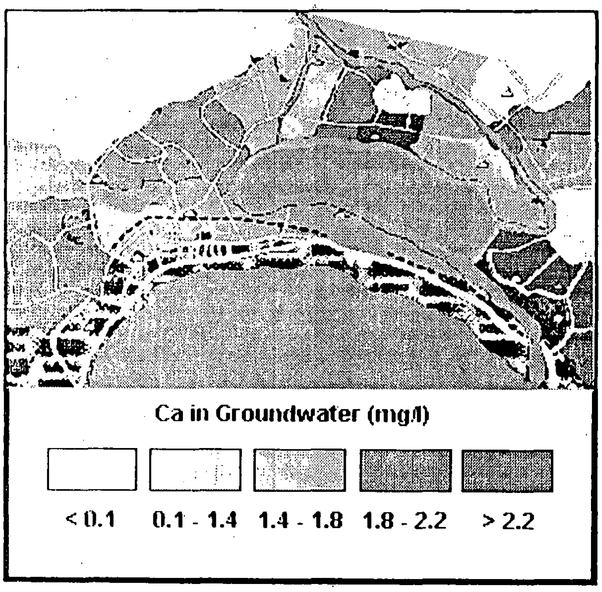


Fig. 5 : Ca distribution in groundwater

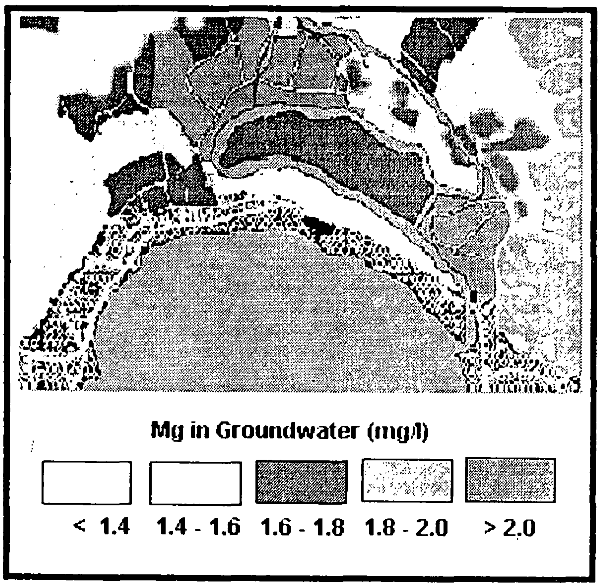


Fig. 6 : Mg distribution in groundwater

Potassium normally occurs in very low concentrations in well water (Figure 7). If water contains high levels of potassium , it may be due to the contribution from fertilizer, detergent, or from other contaminant. In the central part of the area K levels are much higher compare to other parts of the study area.

Excessive evaporation and probable influence of salinity may have contributed to high levels of K. High Potassium concentration observed in the north and north eastern regions is associated with the intense agricultural activities and usage of high dozes of fertilizer and pesticides.

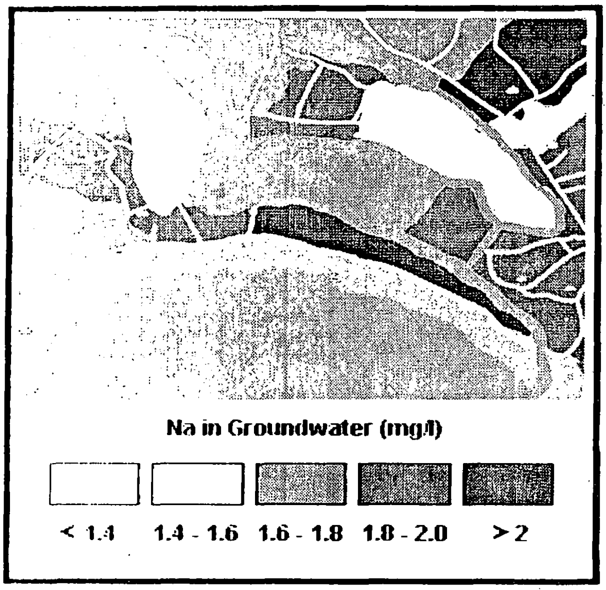


Fig. 7 : Na distribution in groundwater

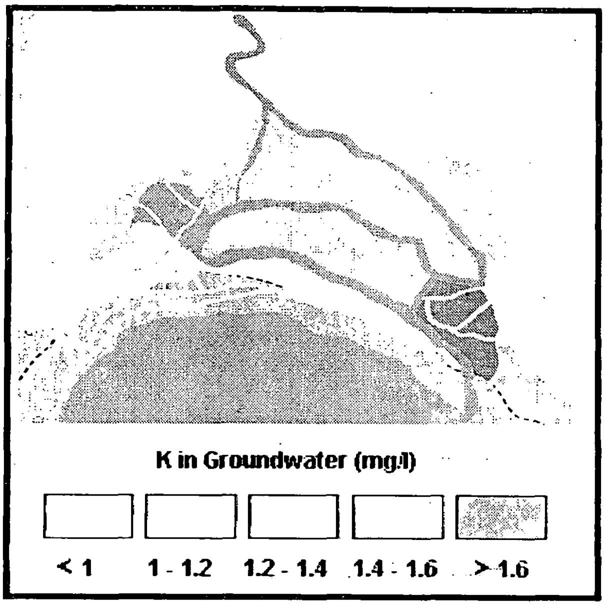
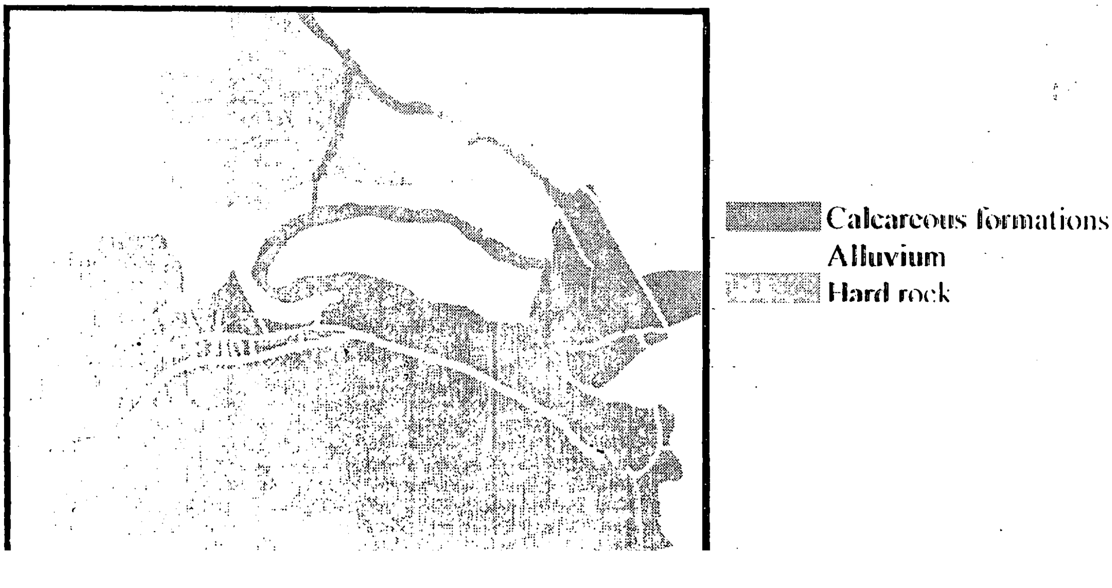


Fig. 8 : K distribution in groundwater

In North Eastern and South region of the area Na+ concentrations are much higher(Figure 8). In the surrounding coastal area Na concentration is higher and exceeds2mg/l. According to the analysis, the Na concentration is low generally throughout the Weligama area.

Groundwater bearing formations according to the chemical analysis

Distribution of Groundwater bearing formations map of the area according to the cation ratios is given in the Figure 9. In Weligama area top unconfined aquifer mainly consists with alluvium sandy formation and calculated Mg^{2+}/ Ca^{2+} is more than 0.9. (Figure. 9).



Along the coastal area and through Polwattumodera ganga river basin is consist with calcareous sand stone, where Mg/Ca ratio varies in the range of 0.5 - 0.7. The field observations conducted in central and western regions helped to demarcate the sandy soil embedded on the hard rock Due to which concentration of Mg^{2+}/ Ca^{2+} is low and water bearing formation can be identify as a hard rock.(Figure 9).

CONCLUSIONS

1) Groundwater discharge area is in the study area is Polwatumdera ganga and coastal line. Recharge is low value due to low hydraulic gradient.
2) Calcium concentration is high due to calcareous unconfined aquifer and Mg^{2+}/ Ca^{2+} is 0.5 to 0.7.
3) There exist two groundwater bearing formations in the of the Polwattumodara basin Ganga and in the eastern and western part of the Weligama bay which could be classified as.
   i. Unconsolidated alluvium groundwater bearing formation where $Mg2+$ /$Ca2+$ ratio is more than 0.9.
   ii. Consolidated crystalline hard rock aquifer
4) In the coastal area due to high concentration of Ca calcareous aquifer is formed. The effect of salinity and the presence of carbonate rock in the areas could possibly contribute to such formation.

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REFERENCES

Barrington R. (1998) : Field Hydrology, John Wiley Sons, United Kingdom.

Bear, J. (1979) : Hydraulics of Ground water. McGraw-Hill, New York

Coory P.G. (1984) The Geology of Sri Lanka, National Museum of Sri Lanka Publication, Colombo, Sri Lanka

FetterC.W.(1994):Applied Hydrogeology, Prentice-Hall Inc., New Jersey

Garg. S.P. (1978): Groundwater and Tube wells, Oxford & IBH Publishing Co. Pvt Ltd New Delhi India.

Gavich.E.K, Lysbewa. A.A, Semionowa A. A, (1980), Practical problems in Hydrogeology,Headra,Moscow, Russia.

Hem, J.D.(1970): Study and interpretation of the chemical characteristics of natural waters. US. Geol. Survey. Water supply paper 1473 Mandel.

S, Shiftan. Z.L (1981), Ground water Resources-Investigation and Development, Academic press. Inc, London U.K.

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Genetic Diversity of Etamba in Sri Lanka

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ABSTRACT

***M. zeylanica* is endemic to Sri Lanka as a wild mango species. RAPD analysis was used to assess the genetic diversity of *M. Zeylanica.* Primer OPA -12 was the most useful in genetic diversity studies of Etamba. Intra- specific variation was found in the population of *M. zeylanica* even within the same climatic zones.**

Keywords : Endemic species, Genetic diversity, *M. Zeylanica,* RAPD

INTRODUCTION

Mangifera zeylanica (Blume) Hook is endemic to Sri Lanka as a wild species commonly known as 'Etamba' (Dassanayake and Fosberg, 1983). It is a slow growing, large plant and bears edible fruit in abundance, but it is not a cultivated species. Etamba is mainly found in Intermediate Zone and Wet Zone forests and conserved *in situ* under the management of the Forest Department. However, the natural population of Etamba is declining in unreserved areas due to destruction of forests and also threatened by habitat loss (Toby, 2002). In these areas, Etamba occurs as scattered plants so that many people do not recognize their inherent value apart from the utility value (timber, firewood, medicine) and thus are not interested in their maintenance and propagation (Kostermans and Bompard, 1993). Mukherjee (1985) has listed *Mangifera zeylanica* as one of the threatened species in the world.

It has been reported that the *M. zeylanica* species also has some several variations in relation to the fruit morphology and quality. Some have larger fruits than others, some are sweet and others sour when ripe, some have very little and others have more of the edible pulp. The loss of genetic diversity of Etamba has also been accompanied by loss of their genes that may be useful in the future emphasizing the need for conservation.

Identification of genetic diversity of Etamba is important for a successful breeding program. Assessment of diversity traditionally has been through morphological characters, which has often found to be less effective. This problem is further compounded by the perennial nature of the mango crop. Therefore, the use of molecular methods could be an efficient way to identify genetic diversity of Etamba. Among the molecular markers, Random Amplified Polymorphic DNA (RAPD) markers are simple, versatile, relatively inexpensive and only nanogram quantities of DNA required (Williums *et al.*, 1990).

RAPD has been used for both genetic characterization and estimation of genetic diversity in mango (Bally *et al.*, 1996; Hemanth kumar *et al.*, 2001; Lopex *et al.*,

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1997; Ravishanker *et al.,* 2000; Schnell and knight 1993; Weeraratne *et al.,* 2005). However, little is known about the genetic diversity of Etamba. Therefore, the objective of this paper is to assess the genetic diversity of Etamba by using RAPD markers.

MATERIALS AND METHODS

Leaf samples of *M. zeylanica* were collected from six plants in five locations to cover the Wet Zone (Ratnapura, Kandy, Peradeniya and Gampola) and Intermediate Zone (Bibile) during the period of January to February 2004. Two samples were able to collect from Gampola and one of them (Gampola 2) known as 'Rathamba' suspected as another Etamba also included in this study. Fruits were collected whenever available and possible morphological characters were recorded using IPGRI descriptor list for Mango.

Total genomic DNA was extracted from both tender and mature leaves of each sample using CTAB method described by Doyle and Doyle (1987) with modifications. Small scale DNA extraction was done using 200 mg of fresh tissue of each variety. DNA concentration and purity were determined by both spectrophotometrically and by visualization of DNA resolved by electrophoresis on agarose gels stained with ethidium bromide. The DNA of each sample was quantified based on UV absorbency measurements.

RAPD analysis was carried out using five arbitrary oligonucleotide primers (OPA-8, OPA-12, OPA-15, OPA-18, and OPA-19) obtained from Operon Technologies Inc. USA. DNA amplification was achieved by the protocol outlined by Williams *et al.*, (1990) with slight modifications. The RAPD reactions were carried out in 25 μl volume consisting 25 ng of template DNA, 1x1.5 mM *Taq* reaction buffer (pH 8.3), 1.2 mM dNTPs and 1.2 mM primer, 2.5 U *Taq* polymerase (Takara Schuzo Co; Ltd, Japan). Amplification was performed in a thermal cycler for 40 cycles after an initial denaturation at 94 °C for 3 min. In each cycle, denaturation for 1 min at 93 °C, annealing for 3 min at 35 °C and extension for 2 min at 72 °C was programmed with a final extension step at 72 °C for 10 min after the 40 cycle. Negative control was used initially to check the fidelity of PCR reaction. Amplified DNA fragments were separated out on 1.4% agarose gel stained with ethidium bromide (0.5 μg ml^{-1}).

RAPD bands were scored for presence (1) or absence (0) of by visual inspection of gel photographs. The sizes of RAPD products were estimated by comparison with 1 kb ladder. The cluster analysis and genetic distances performed by computer software POPGENE version 1.31 (Francis and Boyle, 1999) using unweighted pair-group methods with arithmetic averages (UPGMA) and Nei's genetic distance was used for the RAPD analysis.

RESULTS AND DISCUSSION

All leaf samples of Etamba had matured except for the sample collected from Peradeniya. The OD value of DNA obtained from these samples was 1.1 to 1.6 (260 nm per 280 nm). The quality of these DNA was also confirmed by gel electrophoresis. According to Sambrook *et al.,* (1989), the OD valve of these samples found to be below 1.8 denoting that the DNA could have been contaminated with protein or phenol. Hence, this protocol adopted in this study should be improved to avoid polyphenol contamination for further studies.

Six individuals collected from Wet zone and Intermediate zones were screened with five random primers. Three out of five primers that revealed clear polymorphic amplification pattern were selected for genetic analysis. The gel pattern for the primer OPA12 is shown in Figure1. The number of bands for each primer varied from 2 to18 and the size of bands ranged from 450 to 2000bp. Out of 25 bands 15 were polymorphic and shared among at least two individuals; 9 bands were polymorphic and unique and one band was monomorphic (Table 1). Figure 1 shows eight unique bands against primer OPA-12, of which bands 2.8 kb, 2.1 kb and 1.7 kb specific to individual of Peradeniya; bands 2.7 kb and 800bp specific to Ratnapura; band 400bp specific to Gampola II (Rathamba) and 200bp specific to Kandy.

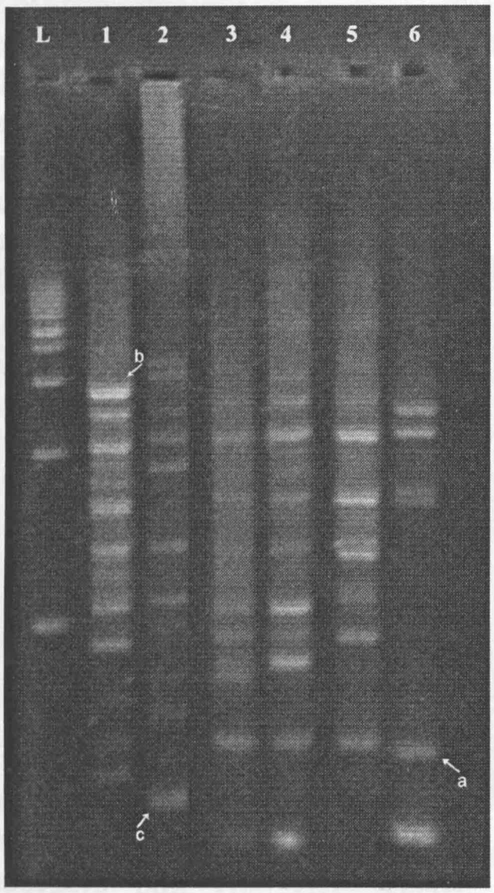

Fig. 1.: RAPD profile for *M. zeylanica* obtained with OPA-12 Primer

L- 1 kb Ladder, 1- Peradeniya, 2- Kandy, 3- Bibile, 4- Rathnapura, 5- Gampola 1, 6- Gampola 2

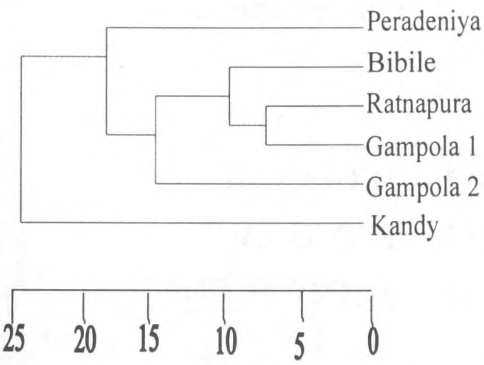

Fig. 2: Dendogram of six individuals of M.zeylanica Using RAPD

All 25 RAPD markers were analyzed to assess the intraspecific variation of *M. zeylanica* species. A dendrogram based on Nei's (1978) genetic distance (Figure 2) revealed that the six individuals were grouped into one cluster, with two distinct individuals of Kandy and Peradeniya. The Etamba collected from Bibila (IZ) appeared to be mixed with Etamba collected from Wet zone in the cluster analysis and was closely connected with Ratnapura and Gampola I. Etamba from Ratnapura and Gampola 1 were more closely related when compared to other individuals of Wet zone. Rathamba collected from Gampola was similar to Etamba. This is the first report of Etamba which is bearing purplish red fruit with prominent beak. According to RAPD analysis, Etamba collected from Bibila (IZ) and those collected from Gampola 1 and Ratnapura (WZ) were closely related to each other even they are different from some morphological characters. However, variation found in Wet zone population could not be compared with Intermediate zone due to limited number of sample collected from IZ.

The genetic distance of individuals of *M. zeylanica* was estimated based on RAPD data using Nei`s genetic distance. Genetic distance between individuals of Wet zones and

Table 1: RAPD markers produced by selected primers for *M. zeylanica*

Primer	Primer sequence	Polymorphic bands		Monomorphic bands	Total
		Shared	Unique		
OPA-12	TCGGCGATAG	10	8	0	18
OPA-15	TTCCGAACCC	4	1	0	05
OPA-18	AGGTGACCGT	1	0	1	02
Total		15	9	1	25

Intermediate zone ranged from 0.223 to 0.916. The lowest genetic distance (0.223) was observed between individuals of Ratnapura and Gampola I which belongs to Wet Zone. The highest genetic distance (0.916) was also observed from Wetzone in between Etamba of Ratnapura and Kandy. A genetic variation exhibited within the population of *M. zeylanica* in same climatic zones (Wet zone) even within the small scale distance eg. Kandy, Peradeniya and Gampola m ay emphasize the relatively wider diversity in the gene pool of *M. zeylanica*.

Leaf characters (leaf texture, leaf margin and leaf shapes) are almost same in all collected samples except leaf tips. All the leaves were thickly coriaceous in texture, lanceolate in leaf shape with flat margin. Individuals collected from Peradeniya, Bibile and Gampola 1 had obtuse leaf tips while others acuminate (1mm- 3 mm) from a rounded apex of the leaves (Figure 3). Fruit bearing period of the tree is October to January in Intermediate zone while those from Wet zone vary from January to March. Fruits could be collected from all the individuals except those from Kandy and Peradeniya. However, the matured fruits could be found only from Bibile indicating that early fruiting observed in IZ. The fruits of Bibile are round in shape about 4.5 cm in length and about 3.5 in width. The skin colour of immature fruits is green and becomes red at maturity. Fruit is fully ripe when it is dropped. However, skin of immature fruit shown in Figure 4 is infected with scab like fungal disease. Unripe fruits collected from Bibile are slightly acidic while ripe fruits are very juicy and fruit can be suck out. The skin colour of Rathama is purplish red even at immature stage, 4-5 cm in length and having a prominent beak. Immature fruits collected from Ratnapura and Gampola 1 are green (Figure 4). It was reported that Etamba in Jaffna and Batticaloa districts of Dry zone are green, small elongated fruits each about 3.8 cm long and 2 cm in wide (Paul and Gunerathnam, 1938). Similar characters reported from Knuckles range belongs to IZ. The value of their inherent characters still not discovered, there may be one or more useful traits that can be used to enrich the cultivated mangoes. Hence, Diversity and distribution of *M. zeylanica* need to be studied in details incorporating more collections represent in three climatic zones and mapped their diversity for future conservation or research purposes.

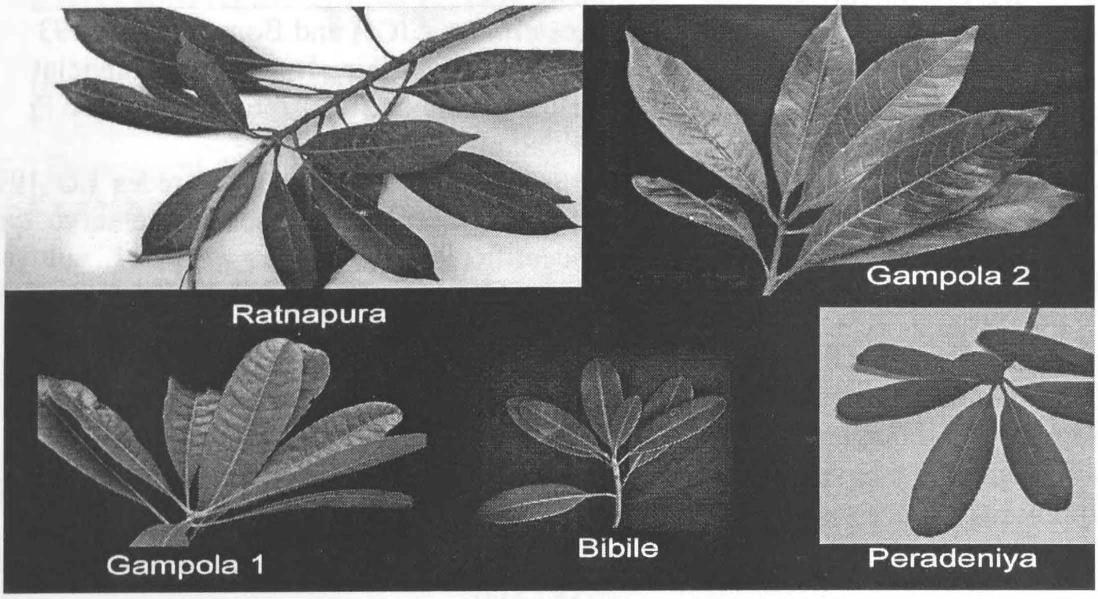

Fig. 3 : Leaf characters of *M. zeylanica* collected from different location

Flat margin, lanceolate, Obtuse ends - Peradeniya, Bibile and Gampola
Flat margin, lanceolate, acuminate ends - Kandy, Ratnapura and Gampola 2

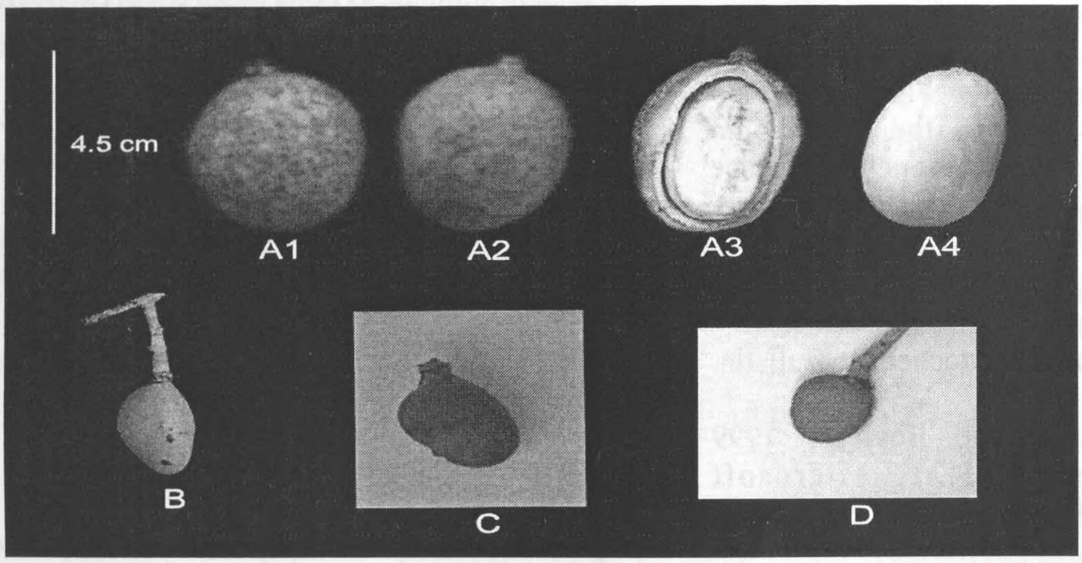

Fig. 4 : Fruit characters of *M. zeylanica* collected from different location

A1- Immature fruit in Bibile, A2- Mature fruit, A3- Cross section of immature fruit,

A4- Stone of fruit, B- Immature fruit in Gampola 1, C- Immature fruit of Rathamba

D- Immature fruit of Ratnapura

CONCLUSIONS

RAPD markers could be used as an efficient tool for estimating genetic diversity in *M. zeylanica* than morphological markers. Primer OPA-12 was the most useful in genetic diversity studies of Etamba. Rathamba collected from Gampola with purplish red fruit and prominent beak was identified as another Etamba tree. Intra-specific variation was found in the population of *M. zeylanica* even within the same climatic zones. This strongly implies the existing rich diversity and the importance of conserving endemic species for future utilization.

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REFERENCES

Bally ISE, Graham GC and Henry RJ 1996 Genetic diversity of Kensington mango in Australia. Australian Journal of Experimental Agriculture. 36: 243-247.

Dassanayake MD and Fosberg FR 1983 A revised handbook to the Flora of Ceylon Vol.IV Published for the smithsonia institution and the National Science Foundation, Washington D.C., Amerindian Publishing Co. Pvt. Ltd. New Delhi.

Doyle JJ and Doyle JN 1987 A rapid DNA isolation procedure for small quantities of fresh leaf tissue. Phytochemist Bullatin. 19: 11-15.

Francis CY, Yang R and Boyle T 1999 POPGENE version 1.31. Microsoft Window-based Freeware for population genetic analysis. http://ftp.microsoft.com/Softlib/MSLFILES/HPGL.EXE (Accessed 27 Nov 2004)

Hemanth Kumar NV, Narayanaswamy P, Theertha PD, Mukunda and Sondur SN 2001 Estimation of genetic diversity of commercial mango (*Mangifera indica* L.) cultivars using RAPD markers. Journal of Horticultural Science & Biotechnology. 76: 528-33.

Kostermans AJGH and Bompard JM 1993 The Mangoes. Their Botany, Nomenclature, Horticulture and Utilization. Academic Press. London.

Lopex VJA, Martinex O, Paredes LO 1997 Geographic differentiation and embryo type identification in *Mangifera indica* L. cultivars using RAPD markers. Hort Science 32(6): 1105-1108.

Mukherjee SK 1985 Description List for mango. International Board for Plant Genetic Resources. Rome. 1-22.

Nei M 1978 Estimation of average heterozygosity and genetic distance from a small number of individuals, Genetics. 20: 583-590.

Paul WRC and Gunarathnam SC 1938 Mango stocks. Tropical Agriculturist. 40: 34-35.

Ravishankar KV, Anand, L and Dinesh MR 2000 Assessment of genetic relatedness among mango cultivars of India using RAPD markers. Journal of Horticultural Science & Biotechnology. 75:198-201.

Sambrook J, Fritsch EF and Maniatis T 1989. Molecular cloning: A laboratory Manual. 2nd Ed. Cold Spring Harbor, New York.

Schnell RJ 1993 Genetic relationship among *Mangifera* spp. based on RAPD markers. Acta Horticulture. 341: 86-92

Schenell RJ, Ronning CM and Knight RJ 1995 Identification of cultivars and validation of Genetic relationships in *Mangifera indica* L. using RAPD markers. Theor Appl Genet. 90: 269-274.

Toby H 2002 In situ conservation of crop wild relatives. www.ipgri.cgiar.org/themes/in_situ_project/wild_relatives/gef.htm. (Accessed 27 Nov 2003)

Williams JG, Kbelik GK, Livak AR, Rafalski JA and Tingey SV 1990 DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. Nuclic Acids Research. 18: 6531-6535.