SUBSURFACE WATER LEVEL OBSERVATION OF CROPLANDS IN MYANMAR WITH KBDI

Kyaw Sann Oo (1), Wataru Takeuchi (2)

[1] GM/Director, Kayah Phoo Group Company Limited, 19 Myae Nu Street, Sanchaung Township Yangon 11041, Myanmar
[2] Professor, The University of Tokyo, 4-6-1 KOMABA MEGURO-KU, TOKYO 153-8505, JAPAN
Email: kyawsannoo@yahoo.com; wataru@iis.u-tokyo.ac.jp

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ABSTRACT: Satellite imageries are utilizing to observe land surface activities and use as input to generate secondary data such as vegetation index, soil index and dryness index in the field of agriculture.
Among the indexes, KBDI is one of Satellite data born index which could observe wetness and dryness of land surface. Its value ranging from 0 as the wettest while the value 8 as the driest. On the other hand, the value 0 represent the water inundated land or waterbody or recent rained area with 100% humidity, while the value 8 represent agriculture drought as hotspot for forest fire or bare land with very less humidity. Vegetation and soil indexes also do the similar representation to land surface vegetation and features.
Crops are generally depending on the soil, weather and availability of water. Therefore, the cropping pattern could be one of indicator to the subsurface water level. The combination of crops knowledges of the specific area, vegetation index, soil index and KBDI are applied to observe subsurface water level in this study and found the relationship.

1. INTRODUCTION

Myanmar is agriculture based developing country. The major crops are paddy, wheat, maize, millet, groundnut(rain), groundnut(winter), sesamum (early), sesamum (late), mustard, malpe (black gram), pedisein (greem gram), butter bean, bocate (cow pea), sultani, sultapya, pelun, pesigon (pigeon pea), peyin (rice bean), pebuygale (duffin bean), pegyi (lablab bean), pegya (lima bean), sadawpe (garden pea), peyazar (lentil bean), peanuk (krishna mung), gram (chick pea), Peboke (soy bean), tea, coffee, sugarcane, toddy palm, potatoes, plantain, cotton (wagyi), cotton (mahlaing 5/6), cotton (long staple), kenaf, rubber and coconut. Among the major crops, paddy is cultivated over the whole country. During monsoon season (June to October) paddy is cultivated using rain water as rainfed cultivation. As monsoon rainfall move from south western coastal line to north eastern inland, rainfed cultivation pattern moving month by month. During the winter season (November to February), pea, pulse, bean and vegetables are cultivated with dew water from the atmosphere. During the summer season (March to May) paddy second crop is cultivated using irrigated water in low land and vegetables, onion, gallic, potato, etc. are cultivated in high land using irrigated water. Major crops are cultivate based on their preferable soil, climate and elevation (Figure 1).

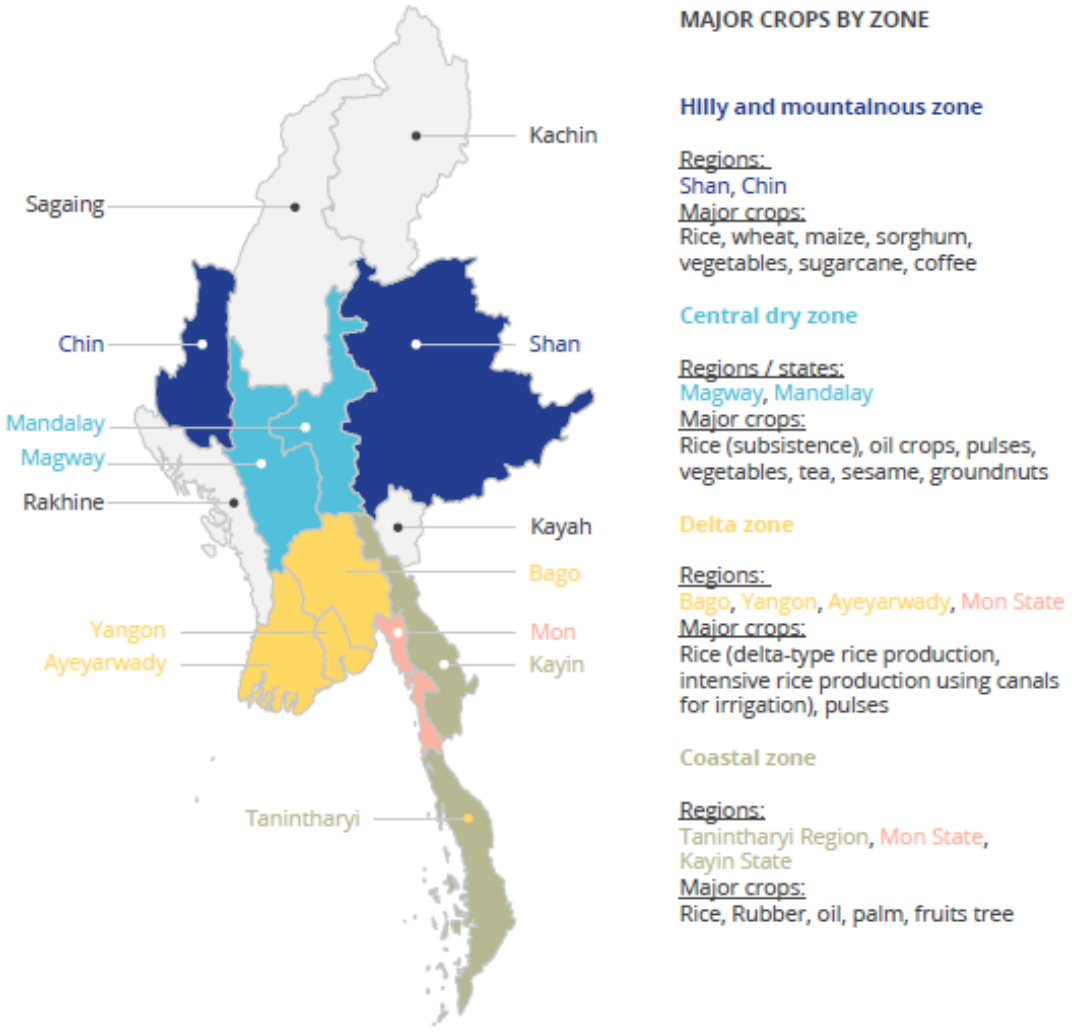


Figure 1: Major Crops by Zone in Myanmar.

1.1 Geography

Myanmar is located at the north western in ASEAN countries bordering with Bangladesh and India at west, with China at north, with Laos and Thailand at east. Her south western has long coastal line at the north east of India Ocean.
Myanmar has three ranges of mountains heading to Himalaya. Western Rakhine Yoma is located between Naf/Laymro/Kuladan rivers basin and Chindwin/Ayeyawaddy rivers basin. Central Pegu Yoma is located just after Ayeyarwaddy river basin to the east. Sittaung river basin is located between Central Pegu Yoma and Eastern Shan Yoma. Shan Yoma continues to the South as Tanintharyi narrow strip and Mague archipelago.

1.2 Satellite data

Satellite-based Drought Monitoring and Early Warning System (S-DMEWS) (Wataru, 2012) developed by the University of Tokyo provide drought warning map, drought index anomaly map, rainfall map, KBDI map and land surface temperature map. Those provided data are available near real-time for drought monitoring, understanding of monthly and annual drought situation, and long-term drought monitoring for Greater Mekong Sub-region countries. Since Myanmar is one of GMS countries, the data covered the whole Myanmar and the archived data are available since 2007.

1.3 Problem

Central part of Myanmar called dry zone area faces water shortage in the summer season. Hydrogeologists are using very old map hydrogeology map, although, S-DMEWS system is

available freely. The existing maps are very old and in small scales, thus, the information are very difficult to apply in real work precisely. Moreover, relationship between subsurface water level, KBDI and crop pattern are separately existence.

2. METHODOLOGY

The extent of study is located between latitude 19° to 23° and longitude 94° to 96° 30'. Yearly temperature is very high in summer season in the region and the summer season start from March to May. Yearly water shortage appears in the region. Therefore, the study is emphasis to observe the subsurface water level of croplands using appropriate technology to understand the water shortage in the region. This study focuses on the central part of the Myanmar where people often faces water shortage for the drinking and utilization in agriculture. Some development projects are focus on solving the water shortage in the area by making dams, pulping, weir, digging, tube well, dug well, overflow well. Though the projects could help immediate need for the area, it is needed to monitor the subsurface water level using appropriate methodology.

2.1 Geology

In the study area, superficial alluvial, fluviatile alluvium and colluvium deposits are found with the geologic time of Holocene (0.01 Ma) to middle Pleistocene (1.8 Ma). Irrawaddy formations are found in lower Pleistocene (2.6 Ma) to upper Miocene (5.3 Ma). Formations of Obogon, Kyaukkok and Pyawbwe are in the Pegu group with the age of middle Miocene (13.8 Ma) to lower Miocene (23 Ma) and Okhmintaung, Padaung and Shwezetaw are also in the Pegu group with the age of Oligocene (23-33.9 Ma). Eocene rocks, Cambrian (485-541 Ma) to Precambian (541-4000 Ma) metamorphic rock and igneous (extrusive and intrusive) rocks (recent to upper Miocene) are also found in the area.

2.2 Hydrogeology

Fresh water in a major river of Myanmar, Ayeyarwady, flows the whole from the north to south of the country. Chindwin River is a main tributary of the Ayeyarwady and joins at Myingyan City northern part of the study area. Thus, the subsurface aquifer of the region is mainly recharge by the the Ayeyarwady River and its tributaries. The hydrogeology and subsurface aquifer flow of the area is presented in the map (figure 2). Subsurface aquifer in alluvial deposits of late Anthropogene (about 12 Ka) and present day are usually fresh and potable with enormous under-ground storage and recharge mainly from perennial rivers and short-lived streams of the region.

Superficial alluvial cover is poor in subsurface aquifer potential, and generally necessary to penetrate into underlying formations to interest subsurface aquifer. Fluviatile alluvium has large subsurface aquifer storage and good recharge conditions with varying in thickness along Ayeyarwady River and other principal river valleys. Most of the alluvium form saturated and semi-confined aquifers and its salinity is generally low and potable except in some shallow aquifers or where associated with the Pegu Group rocks. Subsurface aquifer in the fluviatile alluvium has high yield potential especially near Mandalay and Sagaing, Mu and Chindwin River valleys, upper Samon Chaung and adjacent to the Ayeyarwady River. Colluvium deposit has large subsurface aquifer storage with high subsurface aquifer yield in selected aquifers and large potentiometric fluctuation and are appears along edge of Shan Plateau and those are very good recharge conditions with low salinity. Artesian aquifers in alluvial deposits of middle to late Anthropogene and present times are excellent aquifers and recharge conditions and are mainly fresh in alluvial and slightly saline but potable in proluvial deposits and irrigation by tube wells is feasible. Tube-wells tap subsurface aquifer in thin cover of alluvial deposits over bed-rocks in Irrawaddian (MIO-PLIOCENE) on PEGUAN (EOCENE OLIGOCENE) series are mainly yield saline to brackish waters and has good storage in local areas and their recharge conditions fairly good. Subsurface aquifer in proluvial deposits of middle to late Anthropogene times are mainly slightly saline and potable with good storage in local areas and the recharge conditions is locally excellent.

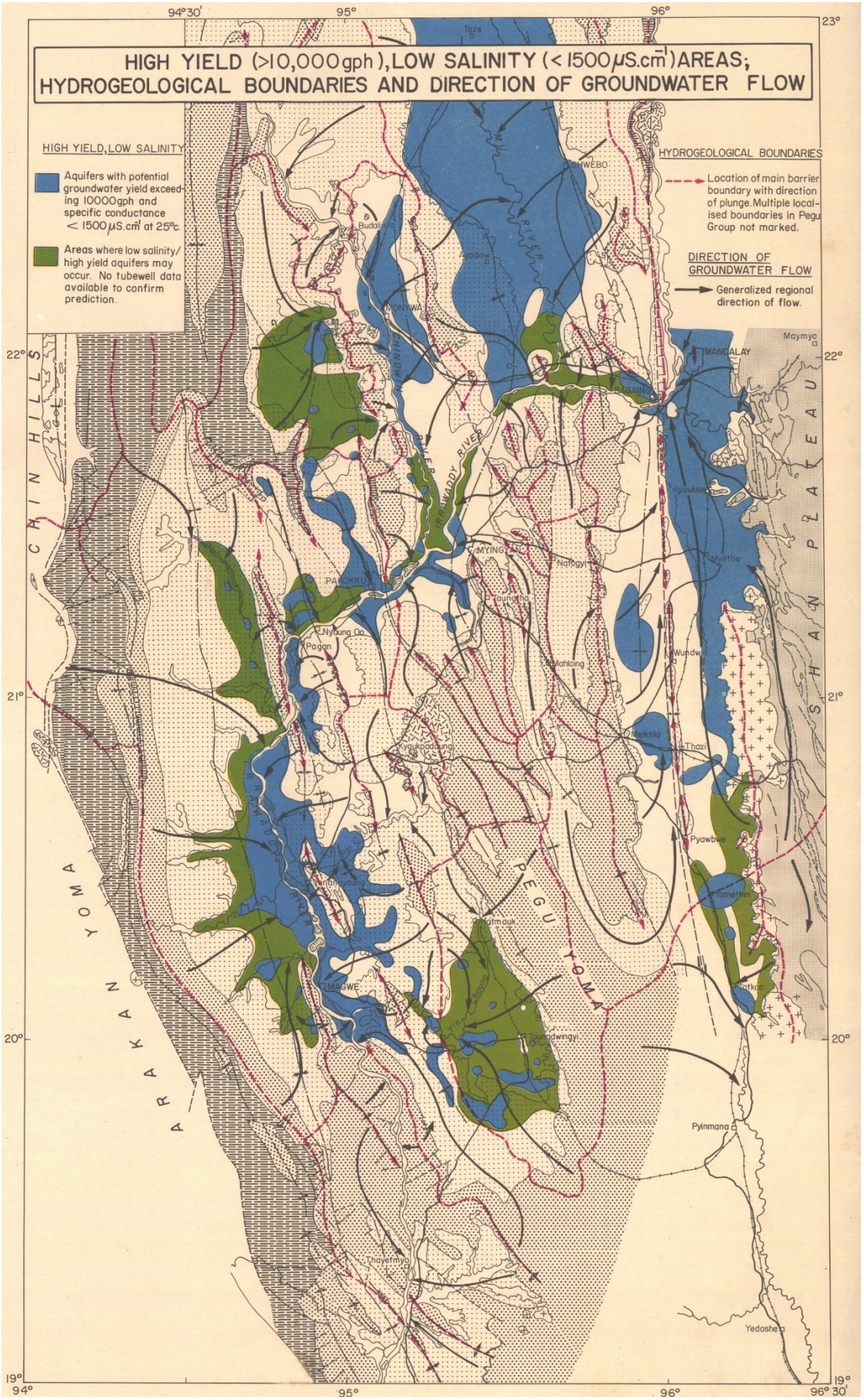
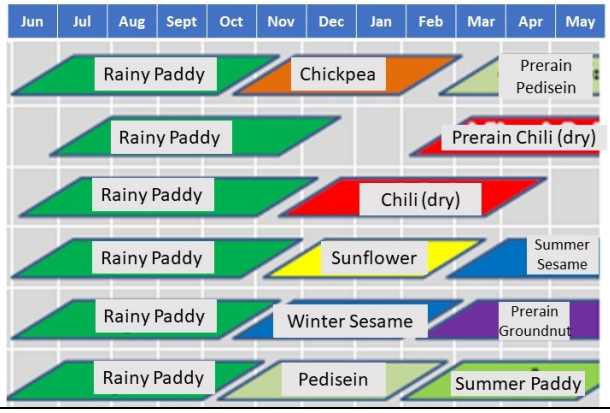


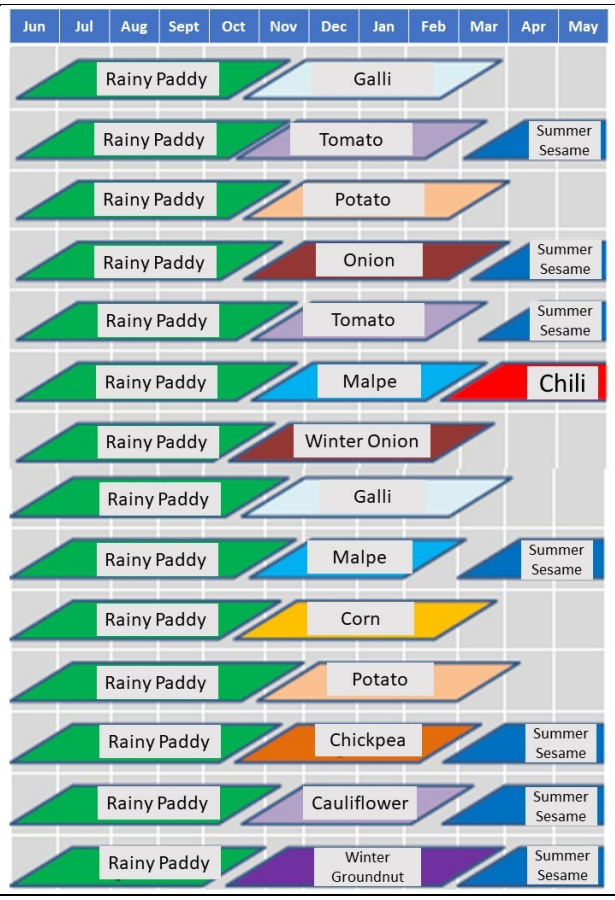
Figure 2: Hydrogeological Boundaries and Direction of Subsurface water flow map of dry zone area of Myanmar.

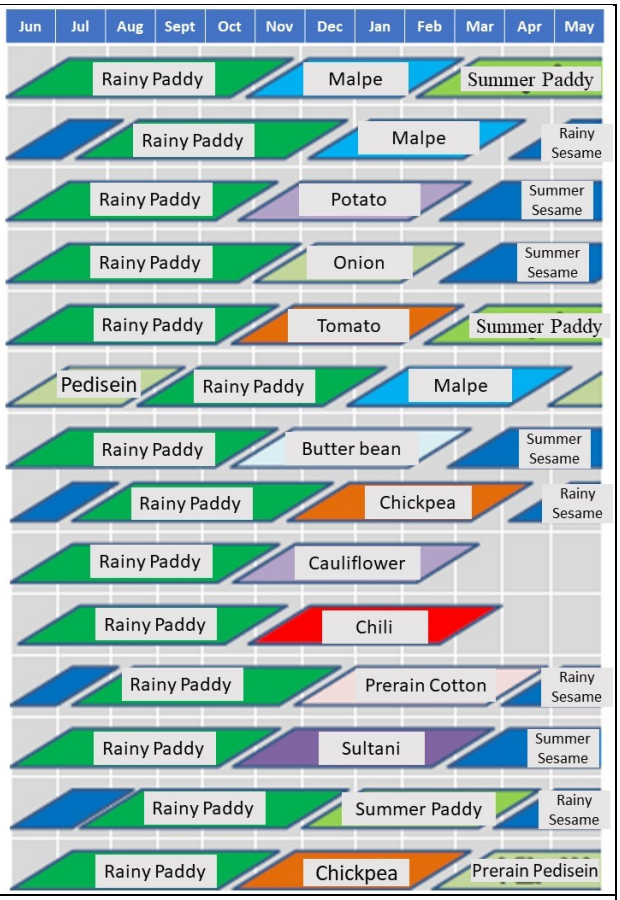
Irrawaddy Formation is principal regional aquifer of the Dry Zone and it consisting largely of poorly consolidated sand with high subsurface aquifer yields in some areas of the Mu, Chindwin and Samon River Valleys, Pale and Taungdwingyi sub-basins, adjacent to the Ayeyarwady River and some tributaries and along major fault systems. In remainder areas smaller subsurface aquifer supplies are available. Subsurface aquifer discharge is to the Ayeyarwady River, other surface drainage systems and springs. Semi confined to confined aquifers, good recharge conditions in elevated areas. Salinity is low and potable in some areas but usually hard. Saline water where associated with the Pegu Group. Obogon, Pyawbwe and Paduang Formations in Pegu Group are regionally considered impermeable except in highly faulted and folded areas and form important aquicludes between more sandy formations of the Pegu Group and also form hydraulic divides thus regionally control direction of subsurface aquifer flow and their aquifers are usually highly saline and rarely some place has high yields and low salinity. Kyaukkok, Okhmintaung and Shwezetaw Formation of Pegu Group comprised massive, fine grained sandstone with occasional clayey sands and form poor, fissured aquifers and generally low yield and high salinity and brine associated with oilfields and good recharge conditions in the Pegu Yoma.
Subsurface aquifer in Irrawaddian Series mainly yield slightly saline to saline waters and some place very saline waters tapped by tube wells and are usually unfit for irrigation but recharge conditions fairly good. Subsurface aquifer in Peguan (Eocene – Oligocene) series is mainly saline to very saline where flushed out yield brackish waters with excellent recharge and storage conditions in Pegu and Arakan Yomas. Subsurface aquifer in fissures of Eocene rocks is mainly low salinity and low yields with very poor storage and recharge conditions. Subsurface aquifer in Plateau Limestone (Archean to Permian) is mainly fresh but hard with which storage in fault-planes and fissures but recharge conditions are excellence. Subsurface aquifer in fissured systems of metamorphic rocks is mainly fresh and low salinity and low yield with very poor storage and recharge conditions. Subsurface aquifer in igneous rocks are low salinity, low yield, sometimes high hardness and their storage and recharge conditions around Mt. Popa is good and it is high potential yield in some basalt areas and low yield in fractured granite. Subsurface aquifer in volcanic rocks (crystalline, ash, tuff and lavas) is mainly fresh storage and recharge conditions very poor except around the Mount Popa.

2.3 Cropping Pattern

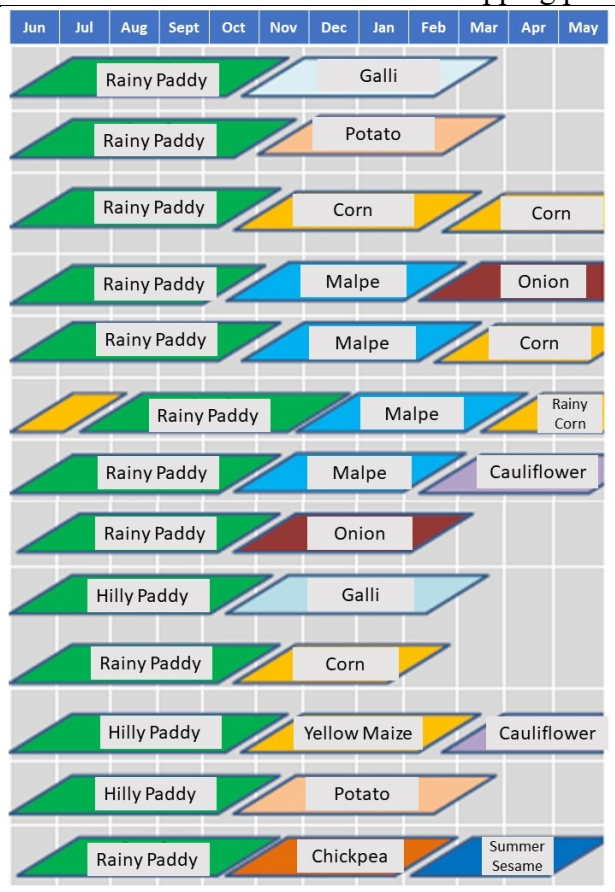
Cropping pattern of major crops are started from June based on the Paddy cultivation starting season (Figure 3). The cropping patterns are recommended by the department of agriculture of Myanmar. Paddy cultivation start by monsoon season since historical period. The cropping pattern is designed based on the monsoon paddy cultivation in June and also based on the irrigation type such dam, rainfed or river pumping. Moreover, the patterns are considering for plain farmland and hilly farmland. When the farmland has assessed to rainfed and irrigation, farmer can be cultivating (3) crops. Vegetables, pulses, cereals and oil seeds are cultivated in cool season after rainfed paddy. Some summer paddy also can be found in the irrigatable area. Based on the cropping patterns Myanmar farmers are cultivating at least (2) crops in a year.

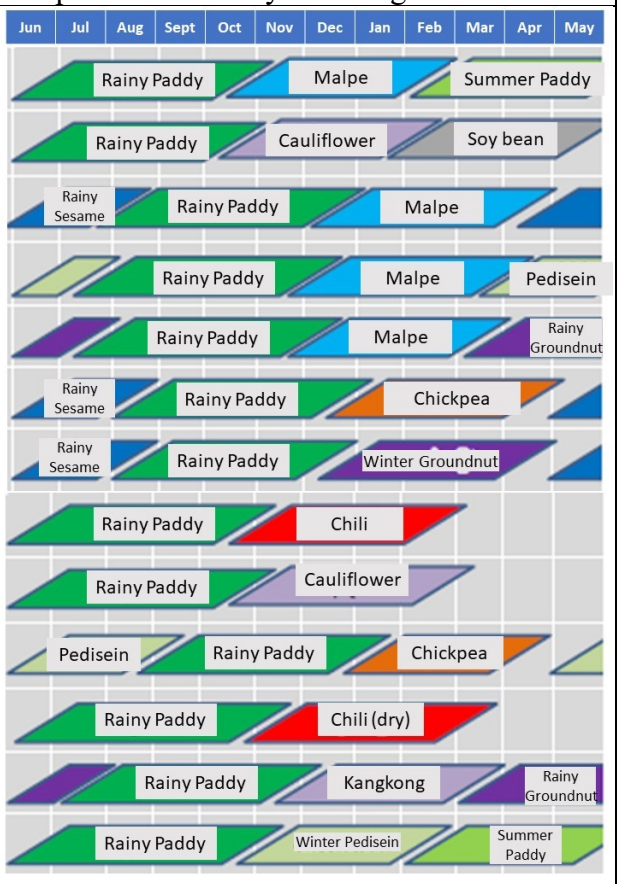




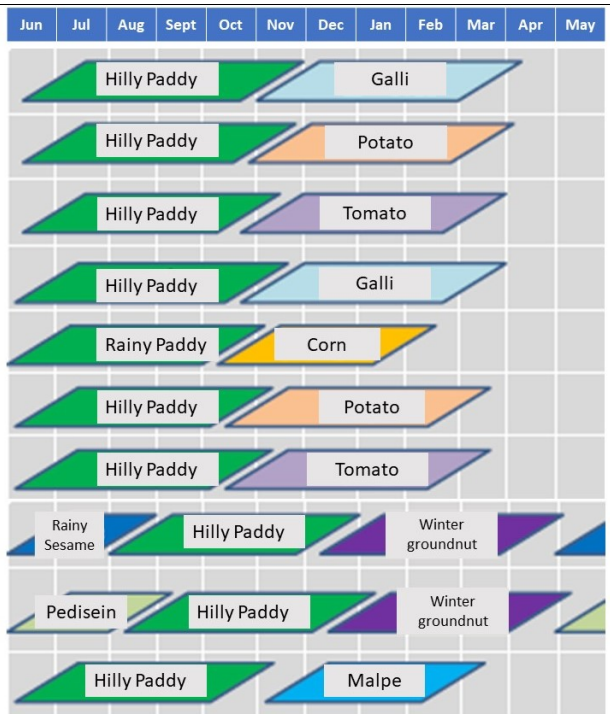


Recommended beneficial cropping pattern in plain farmland by dam irrigation.

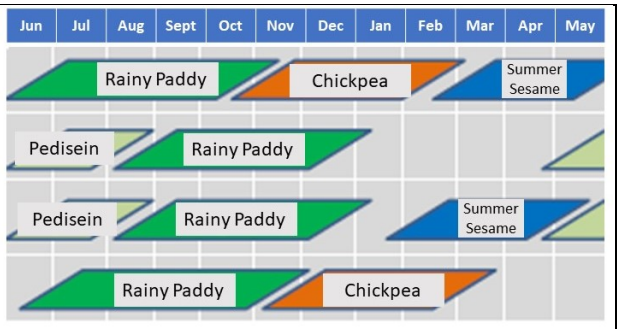




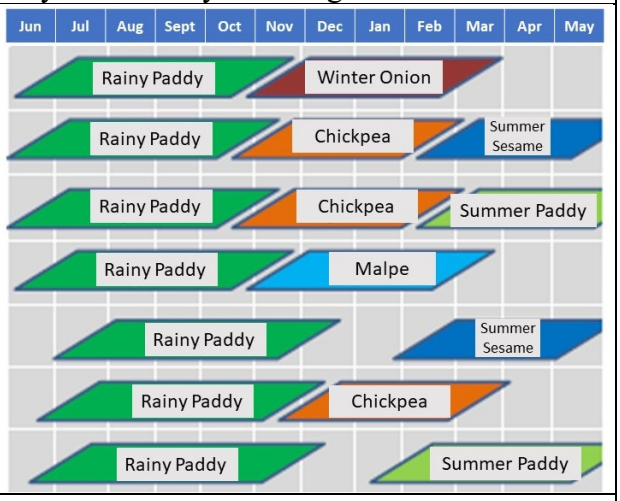
Recommended beneficial cropping pattern in plain farmland by Rainfed.



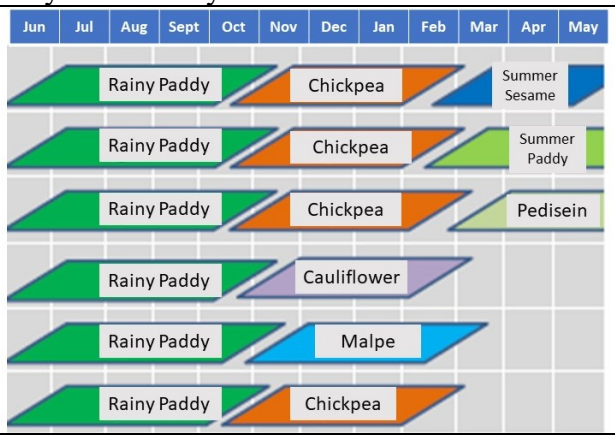
Recommended beneficial cropping pattern in hilly farmland by rainfed.



Recommended beneficial cropping pattern in hilly farmland by dam irrigation.



Recommended beneficial cropping pattern in plain farmland by river pumping irrigation.



Recommended beneficial cropping pattern in hilly farmland by river pumping irrigation.

Figure 3: Cropping patterns.

2.4 KBDI

Keetch-Byram drought index (KBDI) values are available from the system DMEWS which developed at the University of Tokyo. The system provides a drought warning map, drought index anomaly map, a rainfall map, land surface temperature map, etc. Once the internet available, user can specify the location to get the mentioned data freely. Though the data are available on the internet, utilization of the data by the online users are still in limitation.

KBDI for the study is generated using precipitation data of GSMaP and air temperature data of MTSAT (formula 1) (figure 4). The KBDI values are ranging from 0 (wet) to 800 (extremely dry). The sampling points are randomly selected from the dry zone area (Figure 5). Total of 22 samples are selected for the correlation (Table 1). Those points are located in the administration boundary of Magwe Region, Sagaing Region, Mandalay Region, and Nay Pyi Taw.

$$\text{mKBDI} = mKBDI0 - 3.94 \times r + \frac{(1800 - mKBDI_0)(0.968^{\exp(0.0875T + 1.552)} - 8.30)}{1000 \times (1 + 10.88^{\exp(-0.001736R)})} \quad \text{---} \quad \text{(formula 1)}$$

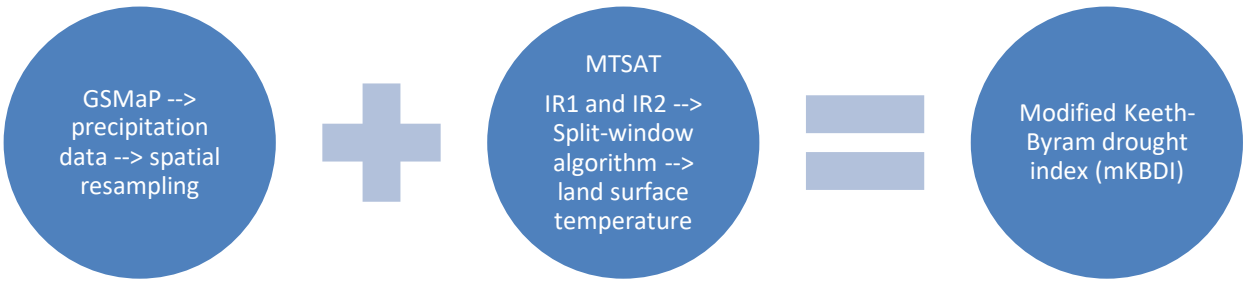


Figure 4: mKBDI generation flow.

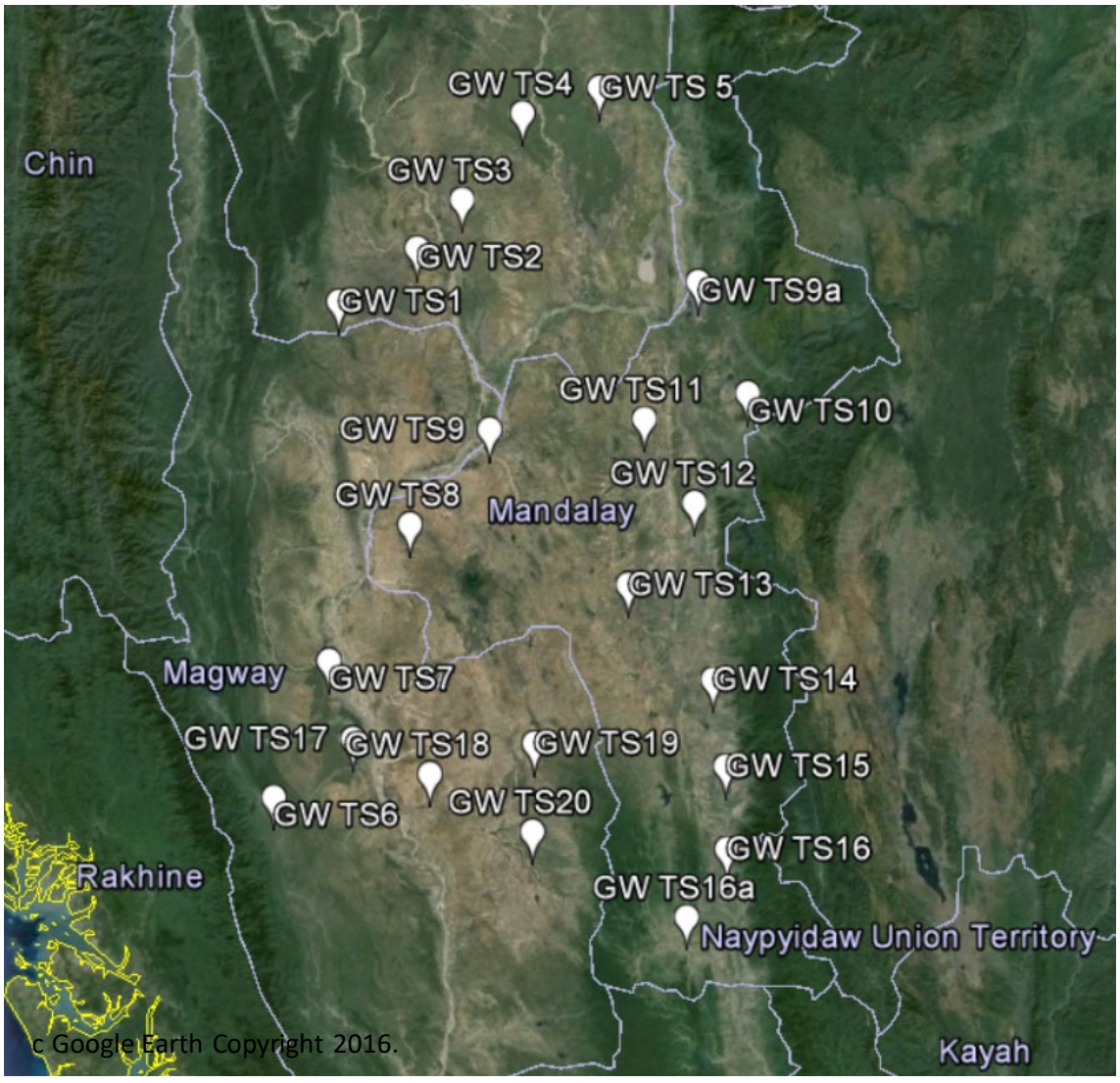


Figure 5: Sampling points.

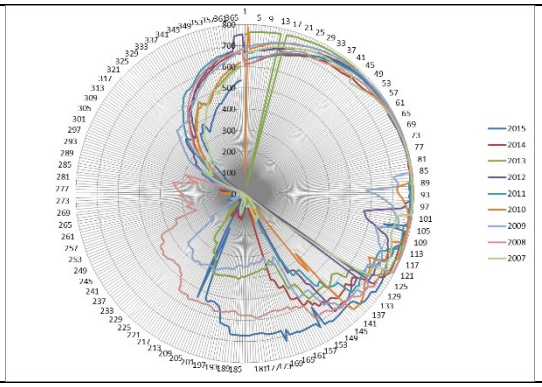
GS	Lat.	Long.	Location	IGBP LC	Geology	Hydrogeology Specific Conductance (SC) in µS.cm^{-1} at 25˚C
1	N21.80	E94.70	Magwe	Croplands	Eocene	SC 3000-6000, high saline
2	N22.00	E95.0	Sagaing	Croplands	Irrawaddy Formation	SC 1500-3000, saline water where associated with the Pegu Group
3	N22.1	E95.1	Sagaing	Croplands	Alluvial deposits on bed	SC 0-1500, aquifers

					rocks (Irrawaddian, Peguan)	potential 10000gph,
4	N22.5	E95.4	Sagaing	Croplands	Alluvial deposits	SC 0-1500, aquifers potential exceeding 10000 gph
5	N22.6	E95.7	Sagaing	Evergreen Broadleaf Forest	Alluvial deposits	SC 0-1500, edge of aquifers potential exceeding 10000 gph
6	N20.0	E94.5	Magwe	Deciduous Broadleaf Forest	Eocene rocks, gw in fissures, low yield	storage and recharge conditions very poor
7	N20.5	E94.7	Magwe	Croplands	Alluvial deposits	SC 0-1500, aquifers potential exceeding 10000 gph
8	N21.0	E95.0	Mandalay	Croplands	Irrawaddy Formation	SC 3000-6000, saline water where associated with Pegu group
9	N21.35	E95.3	Mandalay	Croplands	Alluvial deposits on bed rocks (Irrawaddian, Peguan)	SC 0-1500, aquifers potential exceeding 10000 gph
9a	N21.9	E96.1	Mandalay	Urban and Built Up	Alluvial deposits on bed rocks (Irrawaddian, Peguan)	SC 0-1500, aquifers potential exceeding 10000 gph
10	N21.5	E96.3	Mandalay	Croplands	Alluvial deposits on bed rocks, edge at plateau limestones	SC 0-1500, aquifers potential exceeding 10000 gph
11	N21.4	E95.9	Mandalay	Croplands	Alluvial deposits on bed rocks	SC 1500-3000, high yield potential upper Samon Chaung and good recharge
12	N21.1	E96.1	Mandalay	Croplands	Alluvial deposits on bed rocks, edge at plateau limestones	SC 150-3000, adjacent to igneous rock
13	N20.8	E95.85	Mandalay	Grasslands	Irrawaddy Formation	SC 3000-10000, semi confined to confined aquifers, good recharge conditions in elevated areas
14	N20.46	E96.18	Mandalay	Croplands	Alluvial deposits on bed rocks, edge at plateau limestones	SS 0-1500, aquifers potential exceeding 10000 gph
15	N20.15	E96.24	Mandalay	Croplands	Alluvial deposits on bed rocks, edge at plateau limestones	SC 0-1500, aquifers potential exceeding 10000 gph
16	N19.85	E96.25	Mandalay	Open Shrub lands	Alluvial deposits on bed rocks, edge at plateau limestones	Mainly yield saline to brackish water
16a	N19.6	E96.1	Mandalay	Croplands	Alluvial deposits on bed rocks, edge at plateau limestones	Mainly yield saline to brackish water
17	N20.22	E94.8	Magwe	Water	Alluvial deposits on bed rocks (Irrawaddian, Peguan)	SC 0-1500, Mainly yield saline to brackish water
18	N20.1	E95.1	Magwe	Croplands	Alluvial deposits on bed	SC 0-1500, aquifers

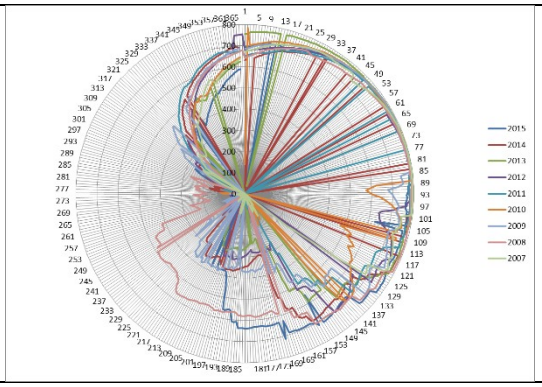
					rocks (Irrawaddian, Peguan)	potential exceeding 10000 gph
19	N20.22	E95.5	Magwe	Croplands	Alluvial deposits on bed rocks (Irrawaddian, Peguan)	SC 0-1500, aquifers potential exceeding 10000 gph
20	N19.9	E95.5	Magwe	Croplands	Alluvial deposits on bed rocks (Irrawaddian, Peguan)	SC 0-1500, aquifers potential exceeding 10000 gph

3. RESULTS AND DISCUSSION

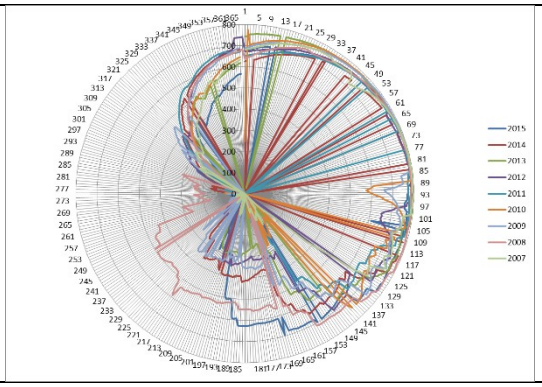
A comparison between KBDI values and sampling plots with hydrogeological data are presented in the figure (figure 6) for 9 years. High KBDI values could be found in the year of 2015 and 2008 for all samples. As shows in comparison figure, each sample is presented as radar chart in yearlong cycle. Using this comparison, the changes of KBDI values can be monitoring and can be correlated with the geology and hydrogeology features of each sampling location. As shows in hydrogeology, the feature has its own capability of subsurface water such as artesian flow, thickness of aquifers, specific conductance, yield capacity, quality of water (salinity). Good quality hydrogeology information is required to improve correlation. Once hydrogeology map is qualified, subsurface water level observation for the crops would be possible by correlating with KBDI values.



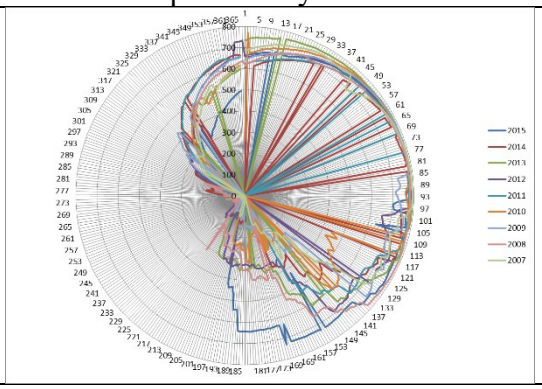
GS 1: high saline



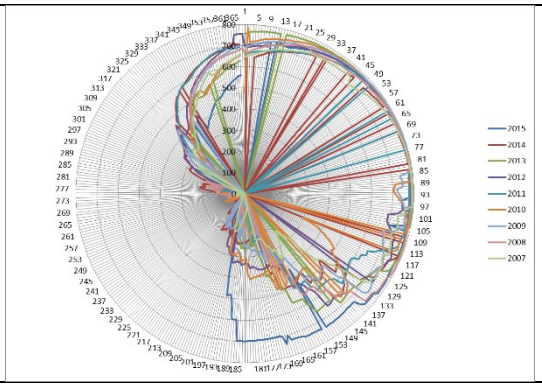
GS 2: Areas where low salinity / high yield aquifers may occur



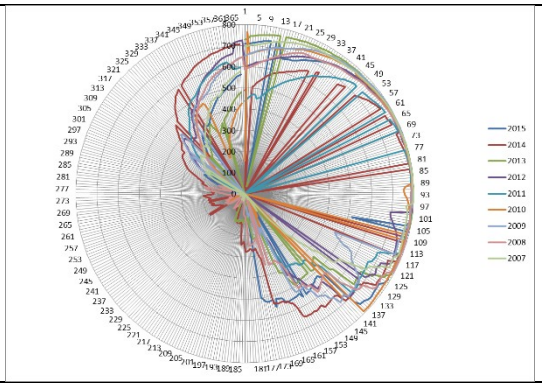
GS: 3 Aquifers potential exceeding 10,000 gph



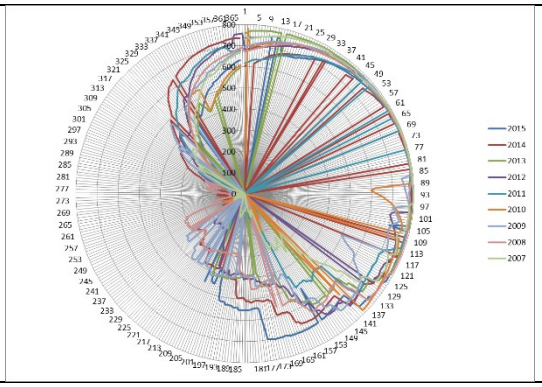
GS 4: Aquifers potential exceeding 10,000 gph



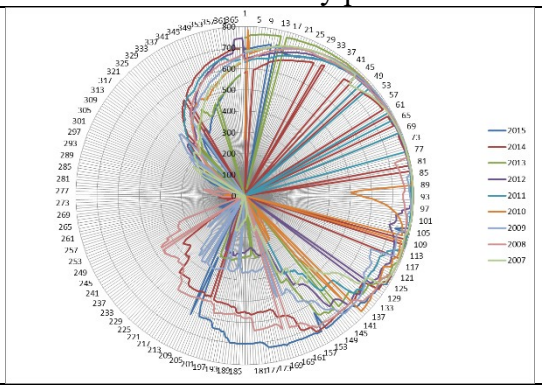
GS 5: Edge of aquifers potential exceeding 10,000 gph



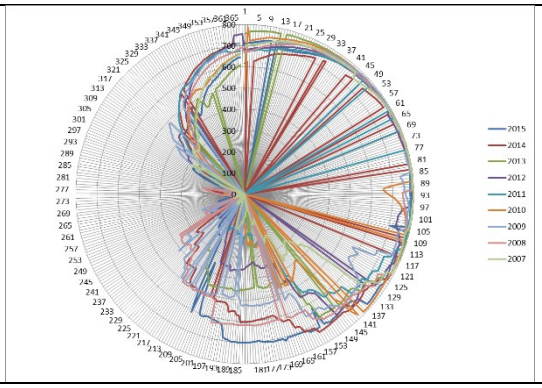
GS 6: Groundwater in fissures; Mainly low salinity and low yield; Storage and recharge conditions very poor



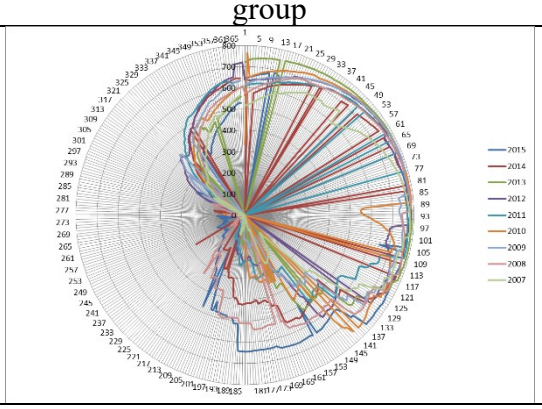
GS 7: aquifers potential exceeding 10,000 gph



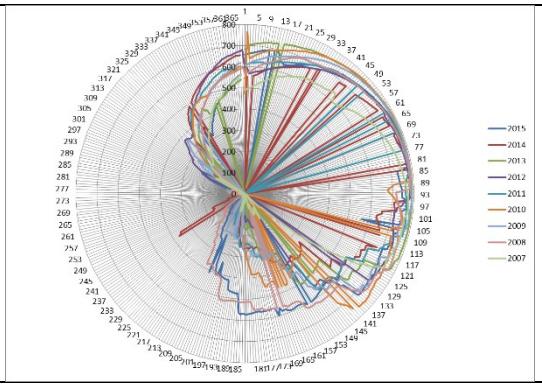
GS 8: Saline water where associated with Pegu group



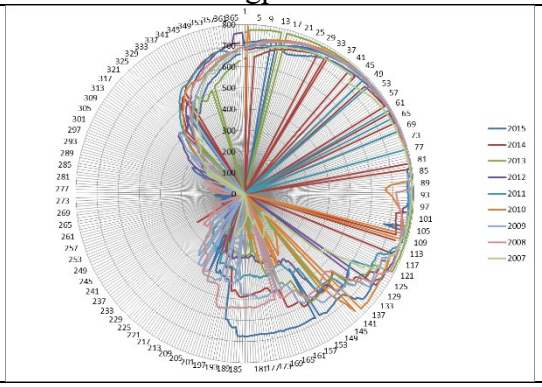
GS 9: Aquifers potential exceeding 10,000 gph



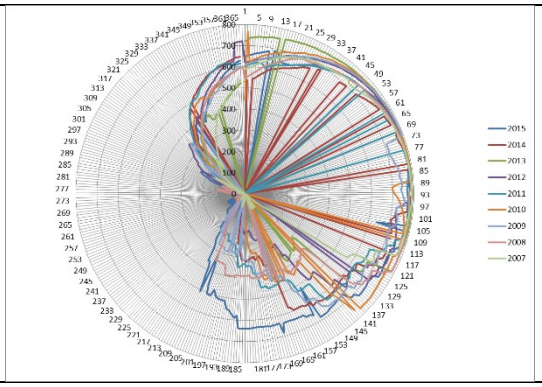
GS 9a: Aquifers potential exceeding 10,000 gph



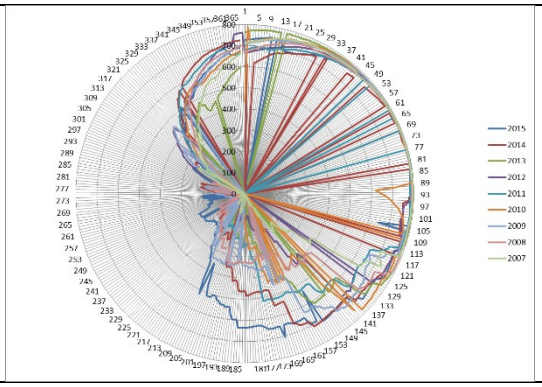
GS 10: Aquifers potential exceeding 10,000 gph



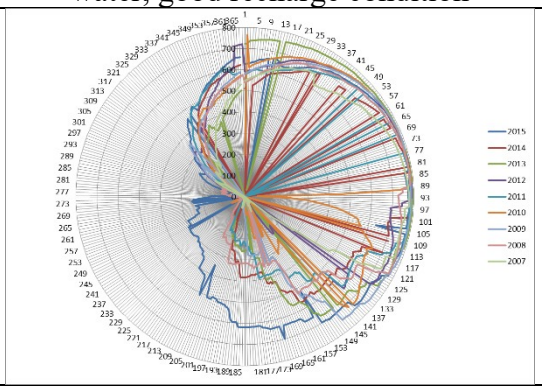
GS 11: Aquifers mainly saline to very saline, good recharge condition



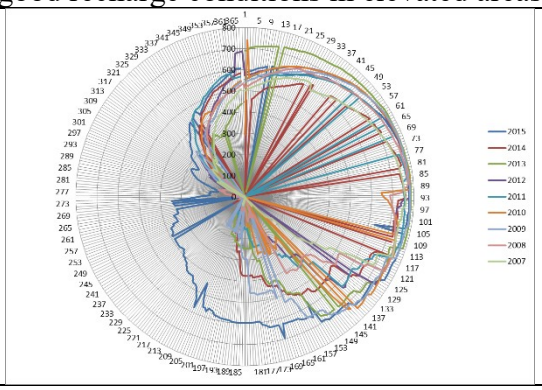
GS 12: Aquifers mainly saline to brackish water, good recharge condition



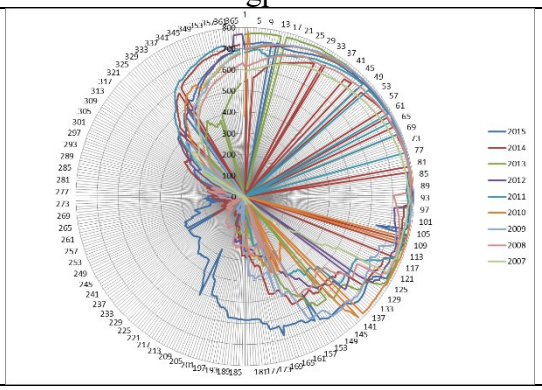
GS 13: Semi confined to confined aquifers, good recharge conditions in elevated areas



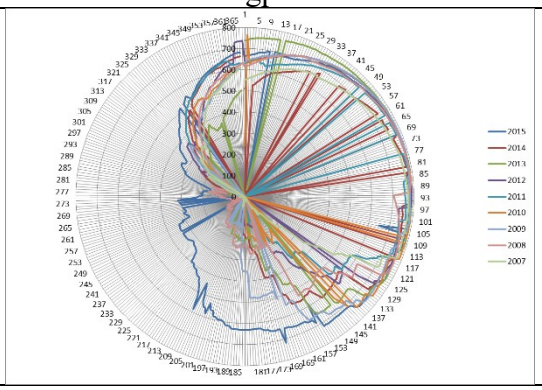
GS 14: Aquifers potential exceeding 10,000 gph



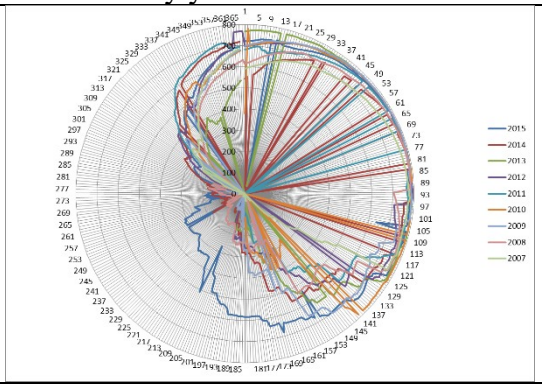
GS 15: Aquifers potential exceeding 10,000 gph



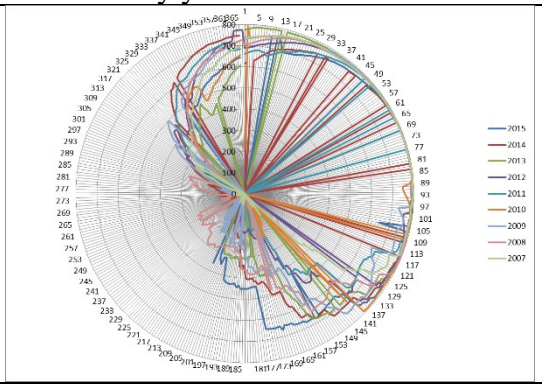
GS 16a: Mainly yield saline to brackish water



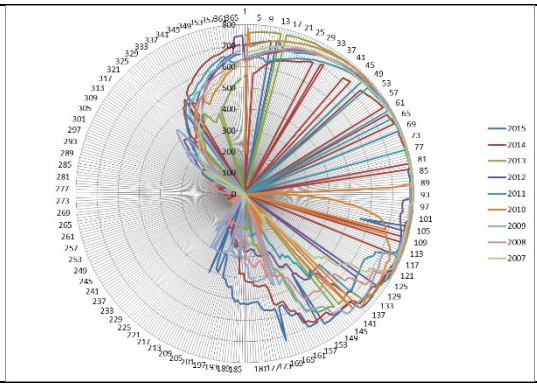
GS 16: Mainly yield saline to brackish water



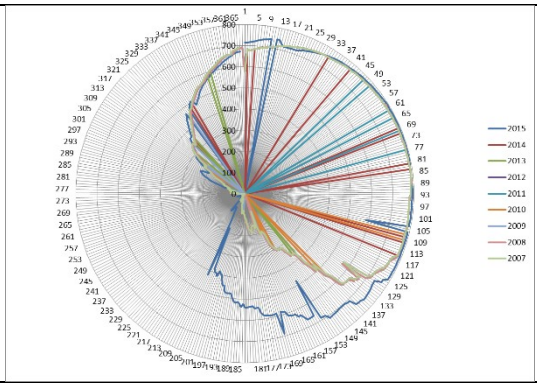
GS 17: Mainly yield saline to brackish water



GS 18: Aquifers potential exceeding 10,000 gph



GS 19: Aquifers potential exceeding 10,000 gph



GS 20: Aquifers potential exceeding 10,000 gph

Figure 6: KBDI values comparison of 22 sampling plots for 9 years (2007 to 2015).

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