INTRODUCTION TO GUNUNGSEWU KARST

**Field Guide
ASIAN TRANS-DICIPLINARY
KARST CONFERENCE**

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Gunungsewu karst stretches 85 km west-east from Parangtritis Beach of Yogyakarta Special Province to Teleng Ria Beach of Pacitan-East Java. The area covers three provinces, namely Yogyakarta, Central Java, and East Java Province. Its north-south width varies between 10 and 29 kms with approximate area of 1300 km². The Gunungsewu karst is adjacent to the Indian Ocean on the south central coast of Java (Figure 1). Elevation range is between zero and 512.5 m above mean sea level, and the highest portions centrally located about 25 km from the cost line.

Figure 1. Landsat ETM depicting Gungungsewu Karst and the surrounding areas

The prevailing contemporary climate in the Gunungsewu karst is strongly influenced by the Northwest and Southeast monsoons, which produce a distinct wet season from October to April and a dry season, which may be extremely arid, between May and September. The annual rainfall, recorded from 14 local rain gauge stations between 1960 and 1997 varies between 1500 mm and 2986 mm annually. Mean annual temperature is about 27° C.

1. Geological and Geomorphological Setting

The Gunungsewu karst is made up of Neogen (Middle Miocene and Upper Pliocene) limestone the so-called Wonosari-Punung Formation (Tmwp). The limestone is composed of massive coral limestone in the south and bedded chalky limestone in

the north (Balazs 1968; van Bemmelen 1970; Waltham *et al.* 1983; Surono *et al.* 1992; Rahadjo *et al.*, 1995). Total thickness of the limestone exceeds 650 m. The coral reef limestone is lithologically highly variable, but dominated by *rudstones*, *packstones*, and *framestones*. Biohermal structures are identifiable, and lenses of volcanic ash are interspersed among the carbonates (Waltham *et al.* 1983). The bedded, chalky limestones become more prominent towards the north and northeast, and dominate the Wonosari Plateau.

The underlying rocks of Wonosari-Punung Formations mostly are volcanic clastic sedimentary rocks of Miocene Epoch (Wuni F., Sambipitu F., Semilir F., Nglanggran F., and Nampol F.). These formations are interchangeable found in some localities being the basements of Gunungsewu Karst. Wuni Formation is composed of agglomerate with tuffaceous sandstone and coarse sandstone lenses. Sambipitu Formation comprises sandstone and claystone. Semilir Formation is made up from tuff, pumice breccias, tuffaceous sandstone, and shale. Nglanggran Formation is composed of volcanic breccias, agglomerate, tuff, and andesitic-basaltic lava. Nampol Formation consists of conglomerate, conglomerate sandstone, agglomerate, sandstone, shale, claystone, and tuff. Another underlying rocks are non volcanic sedimentary rocks of Oyo Formation that consists of tuffaceous marl, andesitic tuff, conglomerate limestone (Surono *et al.*, 1992 and Rahadjo, 1995). Geological map of Gunungsewu Karst and the surrounding areas is presented in Figure 2.

The Wonosari-Punung Formation was uplifted during the late Pliocene and/or early Pleistocene and dipping gently southward at about a 2% gradient, being marked by a high cliff (25-100 m) along the south cost (Balazs 1968; van Bemmelen 1970; Surono *et al.* 1992; Sutoyo 1994). North-south compression associated with tectonic plate convergence produced deformation including intensive northwest-southeast and northeast-southwest jointing and faulting (Balazs 1968; van Bemmelen 1970; Surono *et al.* 1992; Sutoyo 1994, Haryono, *et al.*, 2005). The structure is most complex along the northern boundary.

Figure 2. Geological map of Gunungsewu Karst and the surrounding areas

Qa: Alluvium of Fluvial Deposits; Qv: Alluvium of fluvio-volcanic deposits; Qb: Alluvium of Baturetno Formation; Tmpk: Kepek Formation; Tmwp: Wonosari-Punung Formation; Tmn: Nampol Formation; Tmw: Wuni Formation; Tmj: Jaten Formation; Tmo: Oyo Formation; Tmss: Sambipitu Formation; Tmng: Nglangran Formation; Tms: Semilir Formation; Tomk: Kebobutak Formation; Toma: Arjosari Formation; Tomm: Mandalika Formation (Compiled from Bemelen, 1970 Surono *et al.*, 1992; and Rahardjo *et al.*, 1995)

Gunungsewu Karst physiographically is part of the southern mountain of Java Island (van Bemmelen, 1970), being discontinues hilly range forming plateau morphology (Pannekoek, 1949). The southern mountain was resulted from block uplifted peneplain starting from Late Pliocene. In the northern border, the southern mountain is separated by fault scarp from depression zone of Java. The Gunungsewu Karst itself lies in the eastern section of this hilly range separated from the middle and western part by Graben Bantul. In this section the southern mountain was subjected to faulting and down warping forming Wonosari Depressions and Baturetno Depression within which karstification is limited. The karst surface within the depressions is mantled by deeply weathered clays, up to 10 m in thickness, which are remnants of volcanic ash, intermixed with weathering residue from the limestones (Waltham *et al.* 1983, Samudra, 1983). These two depressions separated the Gunungsewu Karst in southern part with the volcanic clastic sedimentary rocks in northern part of the

southern mountain. These two depressions were resulted from sinus flexure of peneplain, accompanied by small faults, dipping toward the basin.

Uplifting of the area also resulted in several marine terraces and abandoned valley of Archaic Solo River. Reconstructions of the marine terraces were performed by Urushibara (1997), Brahmantyo (198). Three major marine terraces were readily recognized either from satellite imagery or contour map. Identification by the author from DEM derived from 1:25,000 scale topographical map shows that the lowest marine terrace is estimated at the altitude of 112,5m (± 12.5 m) above present average sea level (asl), The middle terraces are about 137.5 m (± 12.5 m) asl, whereas the highest ones are about 200 (± 12.5 m) asl. Minor terraces were also identified by Urushibara (1997) at the approximate altitude of 50 m asl, showing well-shaped cones and dolines at about 20 m asl with extremely small cones and only shallow surface depressions. The marine terraces are also confirmed by the occurrence of cave levels and river terraces at the Sadeng dry valley (Urushibara, 1997) and Baksoka River (Bastra, 1976). Three river terraces, dry cave system, and notches around the mouth of the dry valley are well developed.

Another distinctive morphological feature in the Gunungsewu karst is abandoned/dry valley of former Bengawan Solo River. The Bengawan Solo River that is currently flowing northward to the Java Sea used to flowing southward to the Hindian Ocean sculpturing this abandoned valley (Pannekoek, 1949; Bemmelen, 1970; Urushibara, 1997; Marwanto, 1999). The dried up of the valley was associated with the uplift of southern part of Southern Mountain. This uplift wrapped down the northern part forming depression (previously mentioned Baturetno Basin) and cutting down the former Bengawan Solo River course. Morphological evidence of this wrapping down can be traced through the hanging valley in the southern vicinity of Baturetno Basin Murwanto et al. (1999). Urushibara (1997) suggested that the formation of dry valleys in Gunung Sewu was also conditioned by lowering of sea-level, and establishment of a cool and extremely dry climate. The depth of the dry valley varies between 150 and 250 meter and 450/ wide.

Figure 3. Morphological sketch map of Gunungsewu Karst and the surrounding areas

Gunungsewu karst has been subjected to severe karstification forming tropical karst morphology, the so-called cone or kegel karst. This peculiar type of landform was first reported by Lehmann (1936) and has named as *Gunungsewu Type* in morphologic glossaries. Flathe and Pfeiffer (1965), however, preferred using *sinoid* rather than conical karst to describe the Gunungsewu Karst. Resent work by Haryono and Day (2004) unveiled three variation of the Gunungsewu Kegelkarst to which they described as labyrinth-cone karst, residual-cone karst, and polygonal-cone karst.

Labyrinth-cone karst of Gunungsewu Karst is characterized by development of distinctly linear valleys rather than enclosed depressions, and is dominantly controlled by faults or major joints. In the area, the valley linearity is combined with intervening conical hills. The valleys are dry under normal circumstances. Between the valleys are elongated, interfluvial residual hills, 80–100 m in height, which form long, serrated, ridge-like chains of conical or flat-topped hills without intervening closed depressions. Polygonal-karst is characterized by densely packed or coalesced depressions (cockpits) and dismembered meandering valley networks. Although owing much to dissolution, the polygonal karst of Gunungsewu Karst appears to be strongly influenced by fluvial processes and by the general southerly slope of the plateau. The residual-cone karst is

characterized by conical isolated hills scattered on corrosion plain. The latter karst morphology develops in chalky limestone in which the rocks are less hard and high soluble.

2. Hydrological Situation and Water Resources

General hydrological condition of the Gunungsewu karst does not much differ from the generally karst terrains. The major water flow system is through conduit forming underground river network. The major system and best explored underground river system are Bribin-Baron and Seropan system. The aquifer is characterized by secondary porosities governed by enlarged fissures, bedding planes, and dissolution cavities. However, local variations are distinguished resulted from geological structures and lithological variation. Haryono (2000) suggested that porosities of the epikarst zone of the Gunungsewu karst vary in some localities. Chalky limestone and mudstone have

lower secondary porosity compare to hard coralline limestone. Porosity distribution near the surface is presented in Table 1.

Table 1.. Porosity distribution of epikarst zone in three site of Gunungsewu karst

Sample Area	Characteristics	Porosity		
		Rocks	Solutionally Cavities	Infilled Material
Polygonal karst of Panggang	Coralline limestone, hard and shallow, severe karren and secondary porosity, springs abundant	1.1-14.0	22-52	40.-58.9
Labyrinth karst of Paliyan and Tanjungsari	Deep and hard coralline limestone, well-developed karren and secondary porosity, intensive surface dry valley, few springs are found.	13.-16.6	22-52	36.6-40.2
Residual cone karst of Bedoyo	Bedded limestone, soft and deep, karren dos not develop well, planation is extensive, and springs are rare.	23.1-48.2	< 10	20.6-31.9

From Haryono, 2000

Allogenic recharge from surface river and point recharges through ponors are also well spread in Gunungsewu karst. Point recharges are mostly from ponors draining runoff from closed depressions during rainy season. No surface runoff is encountered during the dry season. Recharge from ponors can be observed through the suspended load of spring water and underground rivers after rainfall event. Major springs in Gunungsewu karst content high suspended load giving a brownish color to the water after rainfall event. Interview with local people unveils that the suspended load of major spring returns to normal condition in two days (in average) unless there is consecutive rainfall. Small springs with discharge less than 5 lt/s usually are less affected by point recharges, hence flowing clean water all year around. Suryanta (2001) found that point recharge of Bribin underground river was responded in four hour after single rainfall event. This fact suggests that point recharge only contributes small percentage to the groundwater and the large one is from water percolation through diffuse and fissure aquifer.

Gunungsewu Karst can be divided in to five Hydrogeologic units (Figure 5.), namely:

1. Panggang sub-system,
2. Bribin-Baron-Seropan sub-system
3. Ponjong sub-system

4. Pracimantoro and Giritontro Sub-System
5. Donorojo-Pringkuku Sub-System

Figure 5. Hydrogeologic units of Gunungsewu Karst

A Panggang sub-system lie in the westernmost part of Gunungsewu Karst is characterized by shallow underlying volcanic clastic sedimentary rocks. These bed rocks can be observed along the escarpment in the western boundary of the karst areas with the graben Bantul. General groundwater flow of the area is likely to the north-west direction, as most of the springs emerge in the northerly and westerly part of the area. However, water flowing southward is also observed with fewer numbers. A number of 20 springs is found along the north and the west vicinity of the karst area.

Bribin-Baron-Ngobaran sub-system was explored comprehensively first by MacDonald and Partners (1984), and latter was studied by Kusumayuda (2005). The recharge area of the system covers not only karst area but also areas of volcanic clastic sediment. The Bribin-Baron underground river system flows to the southwestward and emerges in Baron Beach, and Ngobaran system emerges in Ngobaran Beach.. A number of 10 springs is found in this area where the high discharge are found in Ngobaran (180 lt/s), Baron (8.200 lt/s), Slili (50 lt/s) and Sundak (200 lt/s). Allogenic recharges within this sub system are presented in Table 2. Among those surface watersheds, Tegoan-Sumurup River covers the largest area.

Table 2. Surface watershed of Bribin-Baron underground river system

No	Surface river	Recharge area
1.	Tegoan-Sumurup	Wonosari depression, caprock is bedded limestone of Wonosari Formation the larges
2.	Suci	Wonosari depression, caprock is bedded limestone of Wonosari Formation
3.	Semuluh	Foot slope of karst hills, bedded limestone of Wonosari Formation
4.	Petung	Panggung massive, sediment of volcanic origin (breccias, tuff of Semilir and Nglangran Formation)

Ponjong sub-system is characterized by springs along the N-S fault line scarp separating the karst areas with eastern part of Wonosari Basin. The discharge of the springs is considerably high which is currently used for irrigation purposes. Paddy field is found wide spread in this area. A number of 9 springs is encountered in this area where five of them are Beton (100.9 lt/s), Gremeng (1,870 lt/s), Bendungan (326.5 lt/s), Gedaren (27.6 lt/s), and Ponjong (40.6 lt/s). The groundwater flow in this area is heading to the Wonosari Basin with south-west bearing coinciding with lineaments orientation. Just like the previous sub-system, phreatic surface in this sub-system is unknown.

Pracimantoro-Giritontro sub-system is quite different compared to the other part of Gunungsewu karst, where the most of the springs emerge in the northern side of the karst area flowing to the Baturetno Basin. This phenomenon is contras to the Wonosari Basin where surface water of the basin flows southward sinking to the karst area. Field observation by the author found that the existence of northerly springs in this sub-system is controlled by dip of the bedded limestone. General dip in this area is heading to the Baturetno Basin. A number of 42 springs can be observed in this area, among others which have discharge more than 10 lt/s are Tempur, Banyumetu, Suci, Beji, Karangpulo, Kalisoco, Kedung Maling, Dung Sumber, and Luweng Sapi.

Donorojo-Pringkuku sub-system exhibit general southward groundwater flow, though in detail is controlled by NE-SW and NW-SE joint or fault system. In the north vicinity, groundwater is shallow and being utilized by local people from dug wells.

Groundwater is gradually deeper to the south entering the core of the karstified area. In general, bed rocks of limestone beds in this sub system are shallower than that in the middle part of Gunungsewu. This phenomenon resulted in shallower groundwater level in which in some localities emerges as springs feeding surface rivers. Allogenic recharge in this sub-system can also be identified but mostly become surface river. The major river in the area is Kladen (Baksoka) River of which the upstream is made up from volcanic rock origin.

Water quality analyses in Gunungsewu Karst generally show good quality for water supply (MacDonald and Partner, 1984; Haryono et al., 2000; Sudarmadji et al., 2005). Specific electric conductivity (SEC) of the majority of water indicate a total dissolve solid well below the highest desirable level in drinking water suggested by the WHO. SEC measurements from 32 springs and under ground rivers of Gunungkidul Regency vary between 197 and 559 $\mu\text{S}/\text{cm}$. Higher ESC is encountered only in springs emerge in the shore line. *Telaga* (inundated doline) samples show a large range in SEC varies between 186 and 988 $\mu\text{S}/\text{cm}$. The high value indicates evaporative concentration of the water as the *telaga* dries up.

Suspended sediment measurements in the area indicate a great range of values, depending upon season and aquifer type of the spring. The highest suspended sediment content is encountered in the rainy season, especially at the springs with conduit system. Baron spring is being the highest spring containing suspended sediment in the rainy season. The reason for the high suspended sediment was accounted for the surface rivers (Kali Tegoan, Kali Suci, and Kali Petung) that discharge the springs. Haryono (2000), on the other hand, found that most of karst springs are clean without any significant suspended sediment.

Organic matters in the water as indicated by organic fluorescence in karst area of Gunungkidul also hint at good quality water. Measurement conducted by MacDonald and Partner (1984) indicate that there is little differences among the water samples, which have generally low levels of organic matter. Only 2 samples as of 29 are contaminated by coliform bacteria. Nearly half of these samples are of good quality, having total coliform counts below the minimum detectable level in the area.

Telaga (inundate doline) water, however, exhibit higher content of coliform bacteria indicating excessive faecal contamination with only 2 as of 10 samples being acceptable for supply. Another spring water qualities analyses in Ponjong karst area were carried out by Haryono et al. (2000) of which the coliform bacteria was also found in the two samples as of 11 sample. However the water was still considered as favorable water (B category/could be drink after being boiled). Comparison between analyses conducted in 1984 and the latest analyses however indicates an increase concentration of coliform bacteria. Sudarmadji et al. (2005) unveiled that coliform bacteria counting was also dependence upon season. Higher concentration of Coliform bacteria during rainy season reach a concentration of >2400 MPN/100 ml. Summary of the water qualities in the Gunungsewu Karst are presented in Table 3 and Figure 6.

Table 3. Summary of water quality of Gunungsewu Karst

No	Water sources	Quality	Limitation
1.	Bored well	A or B Category	No or few limitations especially very low concentration of coliform bacteria
2.	Epikarst Springs	A or B Category	No or few limitations especially very low concentration of coliform bacteria
3.	Conduit springs and Underground rivers	B Category	Suspended sediments and low concentration of coliform bacteria
4.	Doline lake	C or B Category	High concentration of suspended sediment, organic matters, and coliform bacteria

Note:

A Category: potable water

B Category: preferable water supply (only need boiling)

C Category: water for fisheries and cattle

3. Soils characteristics and Land Resources

Like in generally karst areas, soils of Gunungsewu karst are mostly shallow or even bedrock. Relatively thick soils scatterly occupy the bottom of closed depressions or dry valleys. Detail soils survey conducted by Research Centre for Soils and Agro-climate in 1994 identified major soils of Haplustalfs, Haplustolls, and Eutropept

Figure 6. Piper and stiff diagram depicting typical bicarbonate water of Gunungsewu Karst. Samples 1-4 are from surface rivers before sinking and samples 5-8 are from underground river

subgroups in the area. Haplustalfs develop in the foot slope of conical karst hills. Top soils of Haplustalfs are characterized by very dark gray color, fine texture, sub angular blocky structure, hard consistency (dry), moderately plastic or sticky consistency (wet), and acid or moderately acid soil reaction. Whereas the sub soils are characterized by very dark gray color, fine texture, sub angular blocky structure, hard consistency (dry), moderately plastic or sticky consistency (wet), and moderately acid soil reaction (Center for Soil and Agro-climate Research, 1994).. Depth of the soils in the Gunungsewu karst are shallow or moderate (mostly less than 50 cm), thus this soils are described as Lithic Haplustalfs. Soils moisture regime of the area is dry (ustic) affected by prevailing monsoon climate. Limitations of this soil for agricultural purposes are heavy workability, drought hazard, and shallow soils.

Haplustolls soils in the area mostly develop in the slope of conical karst hills. These soils are shallower than that of the previously mentioned of haplustalfs. This soils are characterized by grayish dark brown (both in the top and sub soils), fine and

moderately fine texture, moderately angular blocky structure, very hard when dry, very firm when moist, sticky and plastic when wet, neutral or moderately alkaline soil reaction. Major limitation of these soils is shallow soil solum, thereafter these soils are regarded as Lithic Haplustolls.

Eutropept soils identified in the Gunungsewu karst are Fluventic Eutropept and Typic Eutropept. Fluventic Eutropept soils develop from alluvium deposited in the bottom of Palaeo Bengawan Solo valley. Thick sediments along this valley make possible thicker soils to develop. Top soil and sub soil of Fluventic Eutropept are characterized by reddish dark brown, blocky structure, and clay structure. Typic Eutropepts develop in the less karstified areas with undulating morphology. These soils are also relatively thick, characterized by reddish dark brown, granular structure, and clay texture. Summary of soil properties of those four soil sub groups are presented in Table 4.

Most of cultivated lands in the Gunungsewu Karst are marginally suitable or not suitable both for seasonal and perennial crops. Only small percentage of the lands is marginally suitable, specifically that in the bottom of dry valley and undulating karst terrain. The rest area amounting 92% of the area are either permanently or temporary not suitable for seasonal, perennial, and timber crops (Table 5).

Seasonal crops that could be grown with marginally suitable among other are irrigated rice, rain-fed rice, maize, ground nut, sweet potato, and grass. These crops are only marginally suitable to be grown in the bottom of dry valley and undulating areas. The most areas of conical hills, moreover, are not suitable for those mentioned crops. No crops are moderately suitable or suitable being grown in the Gunungsewu Karst. Major limitations encountered in the areas are water availability, rooting condition, soil nutrient availability. Lack of surface water and monsoonal climate are the responsible factor for the limited water availability. The shallow soil depth, in the other hand, results in limited rooting media.

Most perennial crops are also not suitable being grown in Gunungsewu Karst either temporary or permanently. Only orange is marginally suitable, especially if is grown in the bottom of dry valley. The major limitations for perennial crops are the existence of outcrop and rooting media. Timber plants are also not suitable being

grown in the Gunungsewu Karst. Only teak is marginally suitable in the 3% area of Gunungsewu Karst. The rest 97% of the area is not suitable for any timber crops. The major limitations for timber plants are rooting media and water availability.

Table 4. Soil characteristics of the major soils in Gunungsewu Karst

SOIL SUBGROUPS	LITHIC HAPLUSALFS	LITHIC HAPLUSTOLLS	FLUVENTIC EUTROPEPT	TYPIC EUTROPEPT
SOIL SERIES	Temugiring	Gembol	Ngrancah	Mulo
MAJOR OCCURRENCES	Foot slope of karst hills	Slope of conical karst hills	Bottom of Palaeo Bengawan Solo Dry Valley	Undulating karst terrain
Depth	< 50	< 50	> 155	50-100
Drainage	Moderate	Moderate	Moderately slow	Good
Permeability	Moderate	Moderate	Moderately slow	Moderate
Slope	3 – 25	25 – 45	0 - 45	3 – 8
Top Soils				
- Depth	10 – 20	0 – 20	15-25	10-20
- Color	Very dark gray	Dark brown	Reddish dark brown	Reddish dark brown
- Structure	Sub angular blocky	Blocky	Blocky	Granular
- Texture	Clay	Clay	Clay	Clay
- Soil reaction	Moderately acid	Neutral	Moderately acid	Neutral
- C organic (%)	Low	Low	Low	Low
- Nitrogen (%)	Low	Low	Low	Low
- P ₂ O ₅ available	Low	Very low	Low	Very low
- K available	Very low	Very Low	Very low	Low
- Soil erodibility (K)	0,10	0.12	0.12	0.03
- CaCO ₃ Content	0	0.10	0.13	0.13
- Stoniness	-			
Sub Soils				
- Depth	< 30	< 20	> 130	40-80
- Color	Very dark grey-grayish dark brown	Reddish dark brown	Reddish dark brown	Reddish dark brown
- Texture	Clay	Clay	Clay	Clay
- Soils reaction	Neutral	Neutral	Neutral	Moderately acid
- CEC	High	Moderate	High	Low-moderate
- CaCO ₃ content	0	0,1	0.07	0,07
- Stoniness	-	-		
- Workability	Heavy	Heavy	Heavy	Heavy

Note : Excerpted from Centre for Soil and Agro-climate Research, 1994

Table 5. Suitability assessment of major soils in Gunungsewu Karst

SOILS MAP UNIT	Temugiring and Outcrops Complex	Outcrops and Gembol Complex	Sadeng and Ngrancah Complex	Mulo And Gembol Complex
Approximate area	52 %	40%	3%	5%
<i>Seasonal crops</i>				
Irrigated rice	N1s	N2s	S3np	S3wrn
Rainfed rice	N1s	N2s	S3p	S3fn
Maize	N1s	N2s	S3rp	S3n
Soybean	N1s	N2s	S3rnp	S2trf
Green soybean	N1s	N2s	N1r	S3rn
Ground nut	N1s	N2s	S3rp	S3rn
Sweet potato	N1s	N2s	N1r	S3fn
Grass	N1s	N2s	S3wnp	S3wfn
<i>Perennial crops</i>				
Banana	N1rs	N2s	N2w	N2w
Orange	N1rs	N2s	S3wrp	S3wrt
Mango	N1rs	N2s	N2r	N1r
Coconut	S3ns	N2s	N2w	N2w
Cacao	N2r	N2rs	N2w	N2w
Coffee	N2r	N2rs	N1r	N2w
Clove	N2r	N2rs	N2w	N2w
Sugar cane	S3rns	N2s	N1r	N2w
<i>Timber cops</i>				
Teak	N2r	N2rs	N1r	N2w
Mahogany	N2r	N2rs	N2w	N2w
Albizia	S3rs	N2r	N2w	N2w
Leucaena	N2r	N2rs	N2w	N1r
Acacia	N2r	N2rs	S3rp	N1r
Pine	N2r	N2rs	N2w	N2r

From: Excerpted from Centre for Soil and Agro-climate Research, 1994

Note:

S2 : Moderately suitable

S3 : Marginally suitable

N1 : Currently not suitable

N2 : Permanently not suitable

w : Water availability

r : Rooting media

n : Nutrient availability

f : Nutrient retention

s: Outcrop and slope

t: Temperature regime

p: Workability

Though having marginally suitable and not suitable classes, the entire karst area of Gunungsewu are cultivated. Limited land in the area has made farmers to plant any crops in any plot of land. Even farmers extend their cultivated land up to the hill tops. To cope with shallow soils or bedrock, farmers trap the sediments/soils transported by runoff during rainy season by establishing terraces on the hill slopes, therefore farmer get more areas of soil covered land. Crops in this case are grown in the soil that is already trapped in terraces. Terraces are constructed by piling up limestone boulders crashed from karren (Figure 7).

Figure 7. Typical terraces in Gunungsewu Karst

Agriculture is the main livelihood of people living in Gunungsewu Karst. Therefore though there is only limited land resources due to limited arable land, people living in Gunungsewu Karst still engage in farming. No matter the income they raise, farming is the only living that most people can afford. Crop productivity, not to mention, is very low. Productivity of some crops grown in Gunungsewu karst is presented in Table 6. Two cope with this situation, multiple seasonal cropping and multiple perennial crop utilization types are employed. Long adaptation has brought about this land utilization types.

Table 6. Productivity of crops grown in Gunungsewu Karst, sampled from karst area of Paranggupito District (in quintals/hectare)

Seasonal Crops	Productivity	Perennial Crops	Productivity
Rain-fed rice	59.4	Coconut	55.0
Maize	144.0	Clove	2.0
Cassava	477.1	Cashew nut	6.23
Ground nut	16.1	<i>Gnetum gnemon</i>	10.9
Soybean	223	Coffee	3.1

From: Office of Agricultural Affair of Wonogiri Regency, 2004

Multiple cropping in the area constitutes maize+casava+rain-fed rice or ground nut in the rainy season. If the rainy season is prolonged, ground nut or mungbean are grown in for the second rotation. This land utilization type is mostly grown in the

bottom of closed depression, dry valley, and foot slope of karst hills. On the other hand mix gardens are grown in the slope of karst hills or in any land near settlements. The crops grown in mix garden are comparably various, mostly are timber plants, fruit crops or other industrial crops. Detail description of these perennial crops is discussed in the biodiversity section.

Figure 8.
Multiple seasonal cropping between maize and ground nut, planted during rainy season. The combination of crops could be rain-fed rice with maize, or soybean and maize/cassava. The second rotation will be ground nut or left bare.

Figure 9.
Multiple perennial crops dominated by teak plantation. The plants could be combination of timber plants, fruit crops, or other industrial crops.

Those two types of land utilization are related to the self relying living of local farmer. Multiple seasonal crops are intended to fulfill daily needs, whereas multiple perennial crops are functioned as saving. The perennial crops especially the timber

plants are harvested when farmers need extra expenditures such as paying tuition fees of their children and other accidental expenses. In addition to timber plants, farmers usually also have castles of two or more cows for a different saving.

4. Biodiversity

Gunungsewu Karst has been subjected to deforestation since the late 19th century. Since then, biodiversity is less abundant compared to that before late 19th century when the area was still a primary forest. Deforestation has resulted in severe land degradation and extensive bare land. However many species of animal and plant groups are still represented in the area. Identification of larger flora and fauna in the 20% area in the centre part of Gunungsewu Karst by Matala Biogama (2002) found 66 species of plants, 32 species of *aves*, 18 species of mammal, and 23 species of reptile and amphibian (Table 6).

Among the flora listed, almost all of the floras in Gunungsewu Karst are cultivated crops. Those crops among others are *Tectona grandis* (teak), *Cocos nucifera* (Coconut), *Parkia speciosa*, *Musa paradisiaca* (Banana), *Acacia auriculiformis* (Acacia), *Gnetum gnemon*, *Albizia falcata*, and *Anacardium officidental*, are the major commodity crops that are planted in mix garden. Whereas *Zea mays* (maize), *Oryza spp.* (rice), *Manihot utilisima* (Cassava), and *Arachis hipogaea* (ground nut) are planted in the dry field.

Domesticated faunas that have economically important for people of Gunungsewu Karst are cow (*Bos indicus*), lamb (*Capra capra*), and chicken. Almost all of family living in the karst area has cattle of two cows or lambs with more than five chickens. Together with mentioned floras, these cattle constitute the major farming system employed. The faeces of cattle is utilized for organic fertilizer, in vise versa, some crops are used to feed the cattle. Economically, cattle are considered as saving by farmers that are usually sold to pay accidental expenses.

Wild fauna that has economical value in Gunungsewu karst are swiftlets (*Apodidae* Family). The colonies of swiftlets are found mostly in cliff cave facing to the Hindian Ocean. Two species of *Aerodramus maxima* and *Aerodramus fuciphaga* were found in the area (Noerdjito, 2000). Local peoples harvest the swiftlet nests by

descending the cliff with traditional equipments. This breathtaking activity has claimed many lives, but they still keep going on. Environmental problems currently emerge

Table 6. Biodiversity of Gununsewu Karst, sampled from central parts of the area

No	Species	Note	No	Species	Note	No	Species	Note
Large flora								
1	<i>Acacia auriculiformis</i>	+ -	23	<i>Cucumis sativus</i>	+	45	<i>Muntingia calabura</i>	-
2	<i>Albizia falcata</i>	+	24	<i>Cucurbita moschata</i>	+	46	<i>Musa paradisiaca</i>	+
3	<i>Alstonia scholaris</i>	+	25	<i>Curcuma domestica</i>	+	47	<i>Nephelium lappaceum</i>	+
4	<i>Anacardium officinale</i>	+	26	<i>Delonix regia</i>	+	48	<i>Nicotiana tabacum</i>	+
5	<i>Ananas comusus</i>	+	27	<i>Dysoxylum densiflorum</i>	-	49	<i>Oryza spp.</i>	+
6	<i>Annona muricata</i>	+	28	<i>Enterolobium saman</i>	+	50	<i>Pandanus sp.</i>	-
7	<i>Annona squamosa</i>	+	29	<i>Eugenia aquea</i>	+	51	<i>Parkia speciosa</i>	+
8	<i>Arachis hipogaea</i>	+	30	<i>Eugenia cumini</i>	+	52	<i>Phaseolus vulgaris</i>	+
9	<i>Arenga pinnata</i>	+	31	<i>Ficus altissima</i>	-	53	<i>Pinus merkusii</i>	+
10	<i>Artocarpus communis</i>	+ -	32	<i>Ficus benjamina</i>	-	54	<i>Pipturus incanus</i>	+
11	<i>Artocarpus integra</i>	+	33	<i>Ficus septica</i>	-	55	<i>Plumiera acuminata</i>	-
12	<i>Averrhoa blimbi</i>	+	34	<i>Glerichidia</i>	-	56	<i>Psidium guajava</i>	-
13	<i>Averrhoa carambola</i>	+	35	<i>Glycine max</i>	+	57	<i>Punica granatum</i>	+
14	<i>Bambusa spp.</i>	+	36	<i>Gnetum gnemon</i>	+	58	<i>Saccharum officinarum</i>	+
15	<i>Capsicum frutescens</i>	+	37	<i>Gossypium sp.</i>	+	59	<i>Sesbania grandiflora</i>	+
16	<i>Carica papaya</i>	+	38	<i>Hibiscus rosa-sinensis</i>	-	60	<i>Solanum melongena</i>	+
17	<i>Cassia siamea</i>	+	39	<i>Hibiscus tiliaceus</i>	-	61	<i>Sterculia urceolata</i>	-
18	<i>Casuarina junghuhniana</i>	-	40	<i>Ipomoea batatas</i>	-	62	<i>Swietenia mahagoni</i>	+
19	<i>Ceiba pentandra</i>	-	41	<i>Leucaena glauca</i>	+	63	<i>Tamarindus indica</i>	+
20	<i>Citrullus vulgaris</i>	+	42	<i>Mangifera indica</i>	+	64	<i>Tectona grandis</i>	+
21	<i>Citrus maxima</i>	+	43	<i>Manihot utilisima</i>	+	65	<i>Zalacca edulis</i>	-
22	<i>Cocos nucifera</i>	+	44	<i>Manilkara kauki</i>	+	66	<i>Zea mays</i>	+
Aves								
1	<i>Amaurornis phoenicurus</i>	-	12	<i>Lanius schach</i>	+/-	23	<i>Prinia familiaris</i>	-
2	<i>Arthamus leucorhynchus</i>	-	13	<i>Lonchura leucogastroides</i>	-	24	<i>Prinia inornata</i>	-
3	<i>Collocalia esculenta</i>	-	14	<i>Lonchura maja</i>	-	25	<i>Prinia polychroa</i>	-
4	<i>Collocalia fuciphaga</i>	-	15	<i>Lonchura punctulata</i>	-	26	<i>Pycnonotus aurigaster</i>	+/-
5	<i>Collocalia maxima</i>	-	16	<i>Nectarinia jugularis</i>	-	27	<i>Pycnonotus goiavier</i>	+/-
6	<i>Columba livia</i>	+	17	<i>Oriolus chinensis</i>	+/-	28	<i>Spilornis cheela</i>	-
7	<i>Dicaeum trochileum</i>	-	18	<i>Orthotomus sepium</i>	-	29	<i>Streptopelia bitorquata</i>	+/-
8	<i>Dicrurus macrocerus</i>	-	19	<i>Orthotomus sutorius</i>	-	30	<i>Streptopelia chinensis</i>	+/-
9	<i>Ficedula westermanni</i>	-	20	<i>Otus angelinae</i>	-	31	<i>Todirhamphus chloris</i>	-
10	<i>Gallus gallus domestica</i>	+	21	<i>Parus major</i>	-	32	<i>Zosterops palpebrosus</i>	-
11	<i>Geopelia striata</i>	+	22	<i>Passer montanus</i>	-			
Reptile								
1	<i>Angkistrodon rhodostoma</i>		9	<i>Python reticulatus</i>		17	<i>Rana cancrivora</i>	
2	<i>Bungarus candidus</i>		10	<i>Python molurus</i>		18	<i>Rachophorus sp.</i>	
3	<i>Bungarus fasciatus</i>		11	<i>Ptyas korros</i>		19	<i>Draco volans</i>	
4	<i>Dryophis prasinus</i>		12	<i>Ptyas mucosus</i>		20	<i>Hemidactylus intestinalis</i>	
5	<i>Naja sputatrix</i>		13	<i>Trimeresurus albolabris</i>		21	<i>Calotes jubatus</i>	
6	<i>Natrix subminiata</i>		14	<i>Vipera ruselii</i>		22	<i>Mabouya multifasciata</i>	
7	<i>Gonyosoma onxycephala</i>		15	<i>Muticora intestinalis</i>		23	<i>Gecko gecko</i>	
8	<i>Ophiophagus hannah</i>		16	<i>Bufo melanostictus</i>				
Mamam								
1	<i>Bandicota spp</i>	-	7	<i>Hystrix javanica</i>	-	13	<i>Bos indicus</i>	+
2	<i>Callosciurus notatus</i>	-	8	<i>Macaca fascicularis</i>	-	14	<i>Capra capra</i>	+
3	<i>Canis lupus familiaris</i>	+	9	<i>Manis javanica</i>	-	15	<i>Paradoxurus hermaphrodites</i>	-
4	<i>Felis bengalensis</i>	-	10	<i>Microchiroptera</i>	-	16	<i>Rattus spp.</i>	-
5	<i>Felis catus</i>	+	11	<i>P. pardus pardus</i>	-	17	<i>Sus scrofa vittatus</i>	-
6	<i>Herpestes javanicus</i>	-	12	<i>Panthera tigris sondaica</i>	-	18	<i>Viverricula indica</i>	-

Note : + Domesticated/Cultivated - Wild

From: Matala Biogama (2002)

concerning the harvesting swiftlet nest. Difficulties to control the frequencies of harvesting time bring about the decrease of swiftlet population. The decrease of swiftlets population is also caused by the deterioration of its feeding insect habitats.

Figure 10.
Ngungap Beach, one of
swiftlet nesting cliffs in
Gunungsewu Karst. Swiftlets
inhabit caves/notches in the
base of cliffs. Swiftlet nests
are harvested by descending
the cliff through bamboo ladder
and rope

Another undomesticated animal that is currently being faced by farmers as serious problem is long tail monkeys (*Macaca fascicularis*). Deterioration of their natural habitats has made the monkeys expand their food gathering areas up to agricultural lands. A harvest failure is common problem faced by farmers because of that their crops have been razed by monkeys. The monkeys usually inhabit caves and collect food from the surrounding agricultural lands.

Figure 11
Macaca fascicularis (long
tailed monkey) of Gunungsewu
Karst. This monkey dwells in
caves and looks for some
thing to eat in the surrounding
agricultural land

Cave flora and fauna of Gunungsewu karst has not much explored yet. Antropodes as usually being the biggest cave faunal dweller of caves has not also been described thoroughly. Rohmadi (2004) suggested that 11 species of triglobit and stigobit have been found in Gunungsewu Karst, but only four have been described. Those species among aother are *Sesarmoides jacobsoni*, *Parathelphusa convexa*, *Macrobrachium poeti*, *Macrobrachium pilimanus*, *Javanoscia elongata*, *Tenebrioscia antennnata*, *Sesarmoides jacobsoni*. *Javanoscia elongata*, and *Tenebroscia antennnata*.

6. Cultural property and present population

Gunungsewu Karst has been experiencing long history of settlements. Many archaeologists believe that the oldest human kind of Java was from this area. Widespread caves must have provided good shelters that were readily inhabited. Archaeological exploration and excavation have been conducted since early 1990s. The first archaeological works in Gunungsewu Karst was conducted by von Koenigwald and Tweedie in 1935. They were inspired by the finding of Hominid fossils along Bengawan Solo River of which its upstream is from hilly terrain near karst areas of Punung. The remains of cultural evolution from Palaeolithic toward hunting and agriculture can be reconstructed from here (Yuwono, 2004). The artifacts that have been found from Gunungse karst have given significant contribution to the archaeological Pre-Historic theory of Indonesian and south-east Asia.

Koningwald and Tweedie (1935) found very dense scatters of lithic artifacts in Gunungsewu Karst. The implements are generally made of pink (reddish) dark brown blackish silicified tuff, opaque white silcified limestone, and some fossil wood. The artifacts were collected from riverbed of Baksoko River, mixed with pebbles. There are also massive tools still attached to conglomerate boulders on the slopes of the riverbank about 3-4 meters from the bottom of the river. (Simanjutak, 2002). In additions to tools, Koningwald and Twedee found the existence of *Ursus* sp, *Tapirus* sp, *Stegodon*, *Simia*, *Elephas namadicus*, *Echinosore*, *Symphalangus*, and *Hylobates*.

Comprehensive culture evolution of Gunungsewu Karst was presented by Simanjutak (2002) as it is summarized in the following paragraphs. The artifacts found in the Baksoko River were then named as Pacitanian Culture derived from Pacitan, the

nearest town of the area. Pacitanian culture was said to be Middle Pleistocene. This age is confirmed by recent finding of Semah and Semah in 1999 that have succeeded in obtaining habitation chronology covering from 180,000 to 4,500 in Terus Cave. This finding suggests that Pacitanian Culture is older than 180,000. Choppers represent the highest percentage of the massive tools, in addition to flake tools. The flat-iron and horse hoof type are characteristic of the Pacitan Culture. Von Koningwald concluded that the tool found from the area had characteristic attributes of *Chellean* hand-axes. The creator of Pacitanian Culture however, however, is still unclear. No tools found in the area were associated with hominid fossils.

During the late Pleistocene (40,000 until 12,000), there was change of cultural phenomenon. During this period habitations moved to caves or rock shelters from those previously along the river sides. This change had a great impact on cultural development. Life in temporary camps which had previously tended to be nomadic changed to more settled life in cave. This condition facilitated opportunities for innovations. Some typical characteristics of the late Pleistocene are 1) exploitation of caves and rock shelters for habitation and other activities, 2) exploitation of various kinds of rocks for tools, 3) subsistence by hunting, and 4) hominid culture bearers belonging to the species of *Homo sapiens* (Simanjutak, 2002).

Numerous lithic artifacts of waste flakes and flaking tools in the cave indicate that caves also serve as workshop for lithic tool making. However lithic technology was not developed during this period, inferring from rarity of remains compared to waste flacks. The quantity of artifacts gradually decreased in deeper levels. The lithic artifacts tend to be denser in the upper layers indicates that the lithic industry was developed rapidly near the Pleistocene-Holocene transition. Beside lithic tools, the cave dwellers have started to make implements from animal bones, although not as intensive as in the Holocene. The main source of subsistence during the late Pleistocene was hunting of game in the surrounding areas of the caves.

Lithic industry reached their peak in the first half of Holocene. The product of lithic industry consisted Paleolithic, Preneolithic, and Neolithic. Paleolithic tools are core tools from limestone as chopping tools and choppers. Preneolithic traits were represented by flakes and blades, whereas Neolithic traits were represented by

quadrangular adzes of limestone, mollusk shell, and bone fossils. Flake tools are the most common industry of Gunungsewu Karst. Beside lithic industry, a bone industry was very well developed in Gunungsewu karst, especially during Early Holocene. Bone tools in the area are classified as spatulas, points, needles, and tools made of antler.

The Neolithic of Gunungsewu karst displayed unique characteristics with regards to its geographical orientation, technological aspect, and chronology. In the beginning, Neolithic technology was still centered in caves and shelters, representing continuation of the Preneolithic culture. Subsequently Neolithic sites shifted to open sites on plains and hill slopes. The shift from cave to open sites apparently was related to technological development. The plains and hill slope where chert is easy to get for adze manufacturing, were selected as locations for settlements and workshops, rather than caves. Advancements in technology made it possible to exploit trees to build simple houses around the workshop. Neolithic culture is presumed started from 4,000 BP up to 2,000 BP.

Figure 12. Typical of sheltered cave interior in Gunungsewu Karst.
Inset is points from early Holocene industry
From: Yuwono, 2004 with the courtesy of PTKA UGM

The prehistoric time of Gunungsewu Karst was ended in Paleometalic Era. in this era pottery making become more advanced, characterized by the use of paddle and anvil, combine with the use of potter's wheel and polishing technology. The time span covered by Paleomethalic culture was shorter than that of Neolithic. This culture still

existed 700 years ago. This culture did not last long as evidenced by the thinness of the cultural layer in the excavation site.

Gunungsewu prehistoric time culture was prolonged. When the lowland areas and volcanic areas experienced Hindus culture, Gunungsewu Karst still carried on pre-historic culture until better access was opened from the lowland surrounding areas. Hindus culture in Java island has started since the 4th century compare to that in Gunungsewu Karst where no inscriptions were found (Yuwono, 2005, oral communication). As stated before, during 4th century, Gunungsewu Karst was still undergoing Paleometalic Era.

Currently, Gunungsewu Karst is inhabited by approximately 1,113,200 people scatterly throughout the areas. No certain concentration of settlements is found. Population density varies between 281 and 452 people/km² (Table 7). Population growth rate is very low, lower than any other surrounding areas. The major livelihood of the people is still subsistence agriculture. As mention earlier, extensive cultivation is applied reaching to the tops of karst hills. Avery single plot of land is cultivated. Therefore population pressure in the areas is higher than the agricultural carrying capacity as it is indicated by population pressure index that is higher than one (Table 7). Index of 3.41, for example, indicates that there must be 3.41 times more land than that of the existing agricultural land. Present traditions in the Gunungsewu Karst are closely associated with agriculture culture. One of the important traditions is people festivity the so-called *Rasulan* that is held annually after harvesting time.

Table 7. Population of Gunungsewu Karst

District	Density (people/km ²)	Growth rate (%/year)	Population Pressure
Purwosari	281	0.001	1.51
Panggang	282	0.002	2.04
Saptosari	452	0.003	3.41
Tanjungsari	385	0.002	2.85
Tepus	367	0.003	2.57
Girisubo	300	0.004	2
Rongkop	371	0.003	2.67
Paranggupito	345	0.002	3.1

From: Anonymous (2001) and Anonymous (2003)

In addition to agriculture, fishery culture has been emerging since the last two decades, especially in the areas near coastal zone. Inadequate agricultural production, farmers try to get alternative income from fishing in the Hindian Ocean. In according with this new livelihood, sea food restaurants serving fresh fishes are blooming in almost beach tourist resorts. It seems that sea fishing will develop comparably fast in the near future. Local government has been also developing fishery sector through building several new harbors in next five years along the coastline of Gunungsewu Karst.

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