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MEMORANDUM

FOR/TO : All Regional Directors
All Assistant Regional Directors for Technical Services

FROM : The Director

SUBJEC : **TECHNICAL BULLETIN NO. 16 SUPPLEMENTAL GUIDELINES AND PROCEDURES IN THE PREPARATION OF CHARACTERIZATION REPORTS CUM VULNERABILITY ASSESSMENT AND INTEGRATED WATERSHED MANAGEMENT PLANS USING GEOGRAPHIC INFORMATION SYSTEMS (GIS) AND REMOTE SENSING**

DATE :

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1. **The Technical Bulletin**

This Technical Bulletin provides the supplemental guidelines and procedures in the preparation of characterization reports cum vulnerability assessment and integrated watershed management plans using science-based Geographic Information System (GIS), Remote Sensing and some commonly used biophysical and socio-economic processes and methods in pursuant to DENR Memorandum Circular No. 2008-05, otherwise known as “Guidelines in the Preparation of Integrated Watershed Management Plans”. This will serve as guide to all regions and field implementers towards a common framework and understanding as far as implementation of DMC 2008-05 and ensure the effective and efficient management and development of the watershed.

2. **Scope and Coverage**

This Technical Bulletin shall apply to all components of all watershed management and development programs and projects.

3. **Users of this Technical Bulletin**

The intended users of this technical bulletin are personnel of DENR field offices who are involved in planning, implementing and managing of watershed programs and projects.

4. **Definition of Terms**

4.1 **Watershed** refers to a land area drained by a stream or fixed body of water and its tributaries having a common outlet for surface run-off. This include small watersheds with area of 10,000 ha and below; medium scale watershed with area of more than 10,000 ha to 50,000 ha; and large scale watershed with area above 50,000 ha.

4.2 **Watershed Characterization** is the process of describing the biophysical and socio-economic characteristics and features of a watershed in order to have an understanding of the various processes therein.

4.3 **Watershed Management** is the process of guiding and organizing land and other resource uses in a watershed to provide desired goods and services without adversely affecting soil, water and other natural resources.

4.4 **Vulnerability** is the degree to which a system is susceptible to, or unable to cope with adverse effects of natural and manmade (anthropogenic) hazards.

4.5 **Vulnerability Assessment** is an analysis of the relationship between natural and anthropogenic hazards and recipient subject (watershed). The vulnerability assessment identifies the strength and weaknesses of the recipient subject in relation to the identified hazard.

4.6 **Geo-morphometric parameters** describe the physical feature of the watershed, in terms of ruggedness, overall shape, drainage qualities, and dissection.

4.7 **Watershed delineation** is the initial process in the development of management plans where the ridges and stream networks are defined to determine the extent of the landscape from which the different resources are characterized and described.

4.8 **Geographic Information System (GIS**) is a set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986).

4.9 **Remote Sensing** is the technique of obtaining information about objects though the analysis of data collected by special instruments that are not in physical contact with the objects of investigation.

4.10 **Image classification** is defined as the process of classifying multispectral or hyper-spectral images into patterns of varying gray or assigned colors that represent clusters of statistically different sets of multiband data, some of which can be correlated with separable classes, features or materials. According to Weng (2010), some of the basic elements of image interpretation are as follows:

a) Tone refers to each distinguishable variation from white to black and is a record of light reflection from the land surface onto the image.
b) Color refers to each distinguishable variation on an image produced by a multitude of combinations of hue, value and chroma.
c) Size provides another important element in discrimination of objects and features and should be used in reference with its background.
d) Shapes provide diagnostic information in identification such that man-made features often have straight edges while natural features tend to have irregular boundaries.
e) Texture refers to the frequency of change and arrangement in tones.
f) Pattern pertains to the spatial arrangements of objects.
g) Shadow relates to the size and shape of an object.
h) Association helps in identifying human-made features since they tend to indicate or to confirm the existence of another.

4.11 **Vulnerability** is the degree to which a system is susceptible to, or unable to cope with adverse effects of natural and manmade (anthropogenic) hazards. The Intergovernmental Panel on Climate Change (IPCC) also referred to it as the propensity or predisposition to be adversely affected.

5. **Preparation of Characterization Report cum Vulnerability Assessment and Integrated Watershed Management Plan by the Watershed Management Planning Team (WMPT)**

The created multi-disciplinary and multi-sectoral Watershed Management Planning Team (WMPT) composed of representatives from the Regional Office(s), PENRO(s), sectors, LGUs, and watershed stakeholders concerned will conduct the preparation of Watershed Characterization Report cum Vulnerability Assessment and Integrated Watershed Management Plan in accordance to DMC 2008-05.`

6. **Watershed Delineation Using Hydrology and Arc Hydro Processing Tools in ARCGIS**

5.1 Watershed boundary will be delineated, preferably, using the digital elevation models (DEM) derived from advanced geospatial technologies such as satellite imaging and LDAR technology.

5.2 Once the watershed boundary is determined, the geo-morphometric parameters describing the physical features of the watershed (i.e., in terms of ruggedness, overall shape, drainage qualities, and dissection) will be computed using Hydrology and Arc Arc Hydro processing tools in ARCGIS, to determine the quantity and rate of water coming out of the watershed and the responsiveness of the watershed to rain events or its susceptibility to natural calamities like flood and erosion.The geo-morphometric parameters shall be computed using the following formula:

Morphometric parameter	Formula	Description	Units
A. Linear aspects			
1. Stream Order (μ)		Hierarchical rank	Dimensionless
2. Stream length (L_μ)		Length of the major stream	km
3. Total stream length (TL_μ)		Sum of all (L_μ)	km
4. Mean stream length(L_{sm})	$L_{sm} = L_\mu / N_\mu$	L_μ = Total stream length of order "μ" N_μ = Total number of stream segments of order "μ"	km
5. Perimeter (P)			km
6. Stream Length ratio(R_l)	$R_l = L_\mu / L_{\mu-1}$	L_μ= Total stream length of order "μ" $L_{\mu-1}$ = Total stream length of the next higher order	Dimensionless
7. Order length ratio (O_L)	$O_L = L_\mu / L_{\mu+1}$	L_μ = Total stream length of order μ $L_{\mu+1}$ = Total stream length of its next higher order	Dimensionless
8. Bifurcation ratio	$R_b = N_\mu / N_{\mu+1}$	N_μ=Total	Dimensionless

(R_b)		number of stream segments of order "μ" $N_{\mu+1}$ = Number of stream segments of the next higher order	
9.Mean bifurcation ratio	R_{bm}	Average of bifurcation ratios of all orders	Dimensionless
10.Basin length (L_b)			km
11.Rho coefficient (ρ)	$\rho = R_I/R_b$	Ratio of stream length ratio and bifurcation ratio	Dimensionless
B. Relief aspects			
12.Basin relief (B_h)	B_h= H-h	Vertical distance between the lowest and highest points	Dimensionless
13.Relief ratio (R_r)	$R_r = B_h/L_b$	Ratio of basin relief and length	Dimensionless
14.Ruggedness number (R_n)	$R_n = B_h x D_d$	B_h=Basin relief D_d=Drainage density	Dimensionless
15.Melton's Ruggedness number (MR_n)	$MR_n=B_h/A^{0.5}$	B_h= Basin relief A = Area of the watershed	Dimensionless
16. Slope (S)	S= (∆E/L)100%	∆E = $Elev_{max}$-$Elev_{min}$ along the principal flow path L=Length of the watershed along the main	%

		stream (by measuring the valley length and not meandering curve)	
C. Areal aspects			
17. Area (A)			Km^2
18.Drainage density (D_d)	$Dd = TL_\mu/A$	Ratio of total stream length	$Km.km^{-2}$
19.Constant of channel maintenance	$C=1/D_d$	Inverse of drainage density	$Km.km^{-2}$
20.Circulatory ratio (R_c)	$R_c=(4nA)/P^2$	A=Area of watershed P=Perimeter	Dimensionless
21.Elongation ratio (R_e)	$Re=(2/L_b)[(A/n)^{0.5}]$	A=Area of watershed L_b=Basin length	Dimensionless
22.Compactness constant (C_c)	$C_c=P/(4nA)^{0.5}$	A=Area of watershed P=Perimeter	km
23.Drainage Texture (R_t)	$R_t=D_d x F_s$	The product of drainage density and stream frequency	km
24.Stream frequency	$F_s=N/A$	Ratio between the total number of streams and area	Km^{-2}
25.Form factor(F_f)	$Ff=A/L_b^2$	A=Area of watershed L_b=Basin length	Dimensionless
26.Texture ratio (T)	T=N1/P	Ratio of the total number of 1st order stream and perimeter	Km^{-1}
27.Shape index (S_w)	$S_w=L^2/A$	L=Length of	Dimensionless

		the watershed along the main stream (by measuring the valley length and not meandering curve)	
28. Shape factor (S_f)	$S_f=1/F_f$	Reciprocal form factor	Dimensionless
29.Length of overland flow (L_q)	$1/(2D_d)$	Dd=Drainage density	km
30. Leminiscate ratio (K)	$K=L_b^2/4A$	L_b=Basin length A=Area of watershed	Dimensionless

7. Methods and Techniques of Flora and Faunal Assessment

7.1 Flora Assessment

The comprehensive assessment of the vegetation data inventoried is among the crucial factors in the determination of the watershed vulnerability to environmental hazards. Stand structure and diversity analyses in this case will be computed and assessed using the following formulas:

Stand Structure	**Description**
1 Density	Number per unit area $\text{Density} = \frac{\text{number of individuals}}{\text{Area sampled}}$
2. Relative Density	Density relative to the abundance of other species as a function of space and/or time $\text{Relative Density} = \frac{\text{density for a species}}{\text{total density for all species}} \times 100$
3. Frequency	Number of times the species occurs Frequency = number of plots in which species occur

	Total number of plots sampled
4.Relative Frequencies	Relative Frequency = frequency value for a species x 100 total frequency for all species
5. Biomass	Used to express dominance of species, weight of the individuals, useful in analyzing trophic structure and flow of energy. For convenience in the analysis, foliage cover or basal area (sometimes volume) is use to express dominance Dominance = basal area or volume for a species area sampled Relative Dominance = dominance for a species x 100 total dominance for all species
6.Importance Value	Summation of relative density, relative frequency and relative dominance values for each species, standard measurement in forest ecology to determine the rank relationship of species Importance Value = Relative Density +Relative Frequency + Relative Dominance

Diversity Analysis

The following parameters and formulas will be used in the biodiversity assessment analyses:

Biodiversity Parameter	Unit Value	Rationale or Importance	Formula	Data Required
Species Richness	Number of species per stratum	Ready measure of diversity	Total count of species per stratum	Number of individuals per life form
Importance Value (IV)	Relative frequency (RF_i), Relative Cover (RC_i), Relative Density (RD_i)	Change in dominance structure and composition may be evaluated based on these values	IV_i= RF_i+RC_i+RD_i A limit to the number of taxa to be included here should be set accordingly (i.e., >0.5	Frequency, density and basal areas of trees in each stratum
Shannon's Index (H")	Index per stratum pooled across all plots or Index per plot pooled across	Indices may be used for comparison. Index is sensitive to	$H' = \Sigma\, p_I \ln p_I$ where pi ni/N and ni is the abundance of species I while N is the total	Number of individuals per species

	strata		number of individuals	
Simpson's Index (Ds)	Index per stratum poled across all plots	Indices may be used for comparison. Initially a measure of dominance but later translated to diversity	Ds= $1/\lambda$ where λ is $\frac{\Sigma ni(ni-1)}{N(N-1)}$ Ni as defined above	Number of individuals per species
Evenness Measures	Index per plot	Dominance relationships may be shown by the index. Index separates the equitability component of Shannon's Index.	$E=H_{Observed}/H_{max}$, where H_{max} is lnS and S is the number of species	Number of individuals per species
Species accumulation curves	Number of species accumulated per stratum	Plot of species accumulated relative to number of plots allows an extrapolation of the number of species.	Newly encountered species are summed and plotted against accumulated plots. Michaelis-Menten Model was used for extrapolation	Number of unique record of species per plot
Fisher's Index (α)	Index per stratum	This index has been shown to be useful for extrapolation especially, from data generated from small plots.	$S = \alpha \ln(1+N/\alpha)$ With modfication including extrapolation on $\alpha/1000$ and S/1000 basis.	Total number of species and number of individuals per stratum
Rarefaction	Number of individuals and species per stratum	The method enables the comparison of data with different sample sizes $E(S)=\Sigma\left\{1-\left[\binom{N-N_i}{n}\right]/\binom{N}{n}\right\}$	Rarefied sample based on Hulbert's Equation. The MMF model curve fit was used to extrapolate on species per number of individuals basis.	Total number of species and individuals per stratum
Comparative studies	Species collected versus reportedly	This method is straightforward assessment of the species	Listing and measuring percentage similarities	Number of collected materials

	present	collected during the field studies and those obtained from secondary data.		
Multivariate Analysis	Plot data and pooled data for each stratum	The methods enable a visual appreciation of complex information.	Principal Component Analysis (PCA), Correspondence Analysis (CA) and Cluster Analysis (CA)	Number of individuals in plots and summarized in pooled data.
SHE Analysis	Plot data per stratum	The method allows the evaluation of species richness and equitability as unique system components. Enables the detection of abundance distribution in data.	Cummulative computation of lnS, lnE, and H as a function of abundance H' = lnS + lnE	Number of individuals in plots and summarized in successive samples

7.2 Fauna Assessment

The comprehensive assessment and inventory of fauna species is one of the effective tools to address emerging threats on biodiversity of a certain watershed. Knowledge on distribution, abundance, and demography of individual species are crucial input in characterization of watershed as it determines potential conservation and management strategy.

Density Analysis

The following are methods and techniques that will be used in estimating density for wildlife species:

• Total count	Direct count Aims to count all the animals in a specific area which is called the census unit (e.g. National Park, district or any locality). Should be used when: 1. the wildlife area is relatively small (under 10 km2) and oftentimes completely fenced, which means that no animals can enter or leave; and 2. a single species is being counted in a restricted area.
• Sample counts	Aims to estimate the numbers of animals in the total area within the census units from the number counted in a smaller area (sample unit).

	The sample units are divided into blocks/transects then selected transects are searched and counted. The *total population estimate* is found by multiplying the average number of animals in this sample of transects by the total number of transects across the total area (Figure 1). Important assumptions: 1. that all the animals in the sample area or unit are seen and accurately counted; and 2. that animals are spread evenly throughout the whole area or census unit for which the population is being estimated.
• Index counts	A method that aims, by using a standard approach, to produce an indirect measurement of the status of the population in the total area. An *index of abundance* gives an indication of the status of an animal population based on the numbers of animals seen per unit of time or distance, in a particular area over several seasons (Figure 2).
• Time-area counts or Point counts	In this method, the observer counts all the animals (or species) seen in an area from one point over a limited observation period (usually 30-45 min to 1 hour). Observation is repeated at several sites until index stabilizes. The density is estimated with the given formula below: Population Density Index (I) = I = animals counted ÷ πR
• Capture-mark-recapture Method	This is also known as Lincoln-Petersen method, considered as the most basic animal census procedure. A portion of the population is captured, marked, and released. Later, another portion is captured and the number of marked individuals within the sample is counted. Since the number of marked individuals within the second sample should be proportional to the number of marked individuals in the whole population, an estimate of the total population size can be obtained by dividing the number of marked individuals by the proportion of marked individuals in the second sample. Below are the formulae for estimating the population and the population range. *Population estimate* = N/M = (n+1)/(m+1) *Population range* = NR = N ± (*t*)(SE); t95% = 1.96; t99% = 2.58 SE = square root of $[M^2(n+1)(n-m)]/[(m+1)^2(m+2)]$
• Cumulative capture-curve or Leslie graph (*removal method*)	This involves capturing, marking, releasing (or kill) as many animal as possible, eventually 100% are marked (killed). Then, a *cumulative capture curve* (*Leslie graph*) is constructed to yield a population estimate. The regression correlation is being applied here. Y = a + bX

	Where: Y = no. of animals caught X = cumulative no. of animals
Standard terrestrial vertebrates inventory techniques/procedures:	
• Transect Survey of Birds	✓ Standard line transects are established with routes measuring 1.5 to 2.0 kilometers. Each transect route are traversed by one observer traveling by foot at the speed of 15 minutes for every 250 meters of the transect line. ✓ Observations of transect counts of birds are employed for a minimum of 30-40 man-hours of observation time per site. ✓ Observers record the following information/ parameter in a standard data sheet: 1. species name 2. number of individuals, 3. perpendicular distance from the transect line (if possible), 4. type of habitat 5. elevation, 7. strata/vertical distance from the ground and other remarks (seen or heard or flying, perched, participation in mixed feeding parties, call, foraging behavior, seen singly, in pairs or in a flock). ✓ Transect counts are done several times a day especially during early morning, (5:30 am to 10:00 am) and late afternoon (3:00 pm to 6:30 pm), thus completing a total of 40 hours of transect counts for each site. ✓ Each species recorded during the transect counts are included for the computation of Bird Species Diversity (BSD), Bird species richness (BSR), Bird species density (P), Equitability or Even Index (e = Peilou's formula, 1966) to determine the avifaunal composition of the study area.
• Mist-netting of Birds and Volant (flying/Gliding) Mammals (Bats)	✓ Mist-nets are used to catch volant vertebrates such as birds and bats. It is composed of average mesh size of 36 mm and an average height of 2.5 meters in three lengths (6.0, 12.0 and 18.0 meters). ✓ Mist-netting stations composed of 15-25 nets (or 150-250 meters) are set-up in each site and operated for 3-5 consecutive nights and days. ✓ Nets are kept open during the daytime (5:00 am to 6:00 pm) to catch birds (net-day) and left open at night (6:00 pm to 5:00 am) to capture nocturnal birds and bats. ✓ Nets are set 2-3 meters high (as ground nets) while the bottom edges of the net are generally around a meter above the ground. ✓ Mistnets are strategically placed along the tops of ridges, near cliffs and in patches of thick forest growth with possible flyways of understorey birds and bats.

	✓ Occasionally sky nets are hoisted up with a pulley and some nylon rope on top tall tree trunks at a height of about 10-30 meters to capture upper canopy species. ✓ Nets are checked for captured birds every two hours (except during rainy days where it is checked more often) from sunrise to late afternoon. ✓ Nets are guarded for insectivorous bats (net-watching) from 6:00 to 8:00 p.m. and are checked again at 10:00 p.m., as well as 5:00 a.m. the next day. ✓ Netted animals are carefully removed from the nets and placed in cloth bags to minimize stress prior to processing.
• Trapping of Non-volant mammals	✓ Traps are baited with either live annelid earthworms individually tied to the traps or pieces of freshly steamed coconut meat coated with peanut butter, as well as occasional viands of fish/meat. ✓ Most traps are set on the ground (80-90%), often along runways, near holes or among root tangles. Traps are spaced at 5 to 10 meters intervals, while some of traps are strategically placed on tree branches along possible pathways for arboreal species. ✓ Position of the trap and condition of the microhabitat are noted. ✓ Traps are rebaited twice each day - during early morning and late afternoon. One trap-night is equivalent to one trap set for one night. An average of 300-400 trap-nights is set per study site. ✓ Captured animals are identified up to the species level if possible. ✓ The body measurements and weight are taken using a measuring tape/foot ruler/ dial calipers and Pesola spring scales, respectively and recorded on standard field catalogues. ✓ Other basic information is also noted in a field catalogue sheet, i.e. sex, age, habitat, present reproductive conditions, etc. ✓ Animals captured are marked and released except for voucher specimens of probable new records whose identification needs further verification in the laboratory (i.e. examination of cranial features and its measurements). ✓ Species richness, abundance, etc. are determined by the standard number of animals captured per 100 trap-nights (trapping success).
• Transect line for Herpetofauna	✓ A transect line similarly used for birds is selected for each site, and is traversed for observations on herpetofaunal species. ✓ Observations are limited to a maximum perpendicular distance of 25 meters on both sides of the transect. Transect lines are serviced during the day for diurnal reptiles and at night for

	nocturnal reptiles and amphibians. ✓ Species observed per transect count are noted, or collected for verification/identification up to the species level. ✓ Specimens are collected either by hand, insect nets, dip nets (for tadpoles), plastic bags, sticks, pit traps, snap traps, etc. ✓ Captured individuals are processed for body measurements (biometrics: such as snout-to-vent lengths, total length, hindlimbs length, weight etc.) and other baseline information (similarly done for birds and mammals) and recorded on standard field catalogue sheets. ✓ They are later marked and released (except for voucher specimens). ✓ The quadrant method (using small squares) is also employed in some of the sites where herpetofauna is expected. Some ten (10) quadrants measuring 1 x 1 meter are placed at randomly selected sites within an area covering 100 x 100 meters. These quadrants are thoroughly searched during the night especially for amphibians.
Terms	**Description**
1. Sampling	Process of selecting a number of individuals for a study in such a way that the individuals represent the larger group from which they are selected.
2. Sample	Representatives selected for a study whose characteristics exemplify the larger group from which they are selected.
3. Inventory	Process of making a detailed, itemized list, report, or record of things.
4. Survey	Process of estimating the population and determining the location or distribution of organisms and their habitats for the purpose of better managing the land. **Factors affecting the accuracy and precision of sample surveys** ✓ **Visibility of animals.** The results of sample surveys are more accurate for large, dark bodied animals such as elephant, buffalo and sable, which are easily seen. ✓ **Type and state of habitat.** It is more difficult to carry out sample surveys in hilly or mountainous areas. Sample surveys are normally carried out in the dry season when animals are easier to see because many of the trees will have lost their leaves. ✓ **Animal behaviour.** Sample surveys of animals found in large herds can be inaccurate, as they are not easily counted. ✓ **Distribution of habitat.** Wildlife is usually found where there is food, water and shelter. So the survey needs to sample all types of habitat equally.

5. Census	Procedure of systematically acquiring and recording information about the members of a given population.
6. Census index	Refers to a count or ratio which is relative in some sense to the total number of animals in a specified population.
7. Density	Refers to abundance or the number of individual per unit area.
8. Systematic sampling	Process of selecting individuals within the defined population from a list by taking every Kth individual (e.g. every third, etc.).
9. Random sampling	Process of selecting a sample that allows individual in the defined population to have an equal and independent chance of being selected for the sample.
10. Stratification	Procedure of grouping sampling units into categories or into different layers (strata) on the basis of a distinguishing characteristic (e.g. vegetation types, water availability, etc).

8. Methods and Techniques for Socio-Economic Assessment

The following will be the methods to be used in the collection and analysis of the following variables or indicators of the socio-economic factors in the characterization of a particular watershed.

Characteristics	Purpose	Method
1) Demographic Condition		
Household profile (age, sex, education, marital status, etc.)	For understanding demographic condition	Data collection and analysis
Primary and secondary occupation	-do-	Data collection and analysis
Literacy (male and female)	-do-	Data collection and analysis
Livelihood options (farm and non-farm activities)	For watershed development plans	Data collection and analysis
2)Agriculture		
Cropping systems	To introduce new cropping interventions and management to bridge yield gaps	Sampling/ survey
Crop-wise input use (seeds, fertilizers, organics, pesticides, etc.)	-do-	Sampling/survey
Yields obtained	-do-	Sampling/survey
Trends in area	-do-	Historical records
Trends in cop production	-do-	Historical records

Trends in crop yield	-do-	Historical records
Land ownership	Land and water management and crop planning	Sampling/survey
Land use pattern	-do-	Sampling/ survey
Area, production and yield	-do-	Sampling/survey
Crop utilization and commercialization	-do-	Sampling/survey
Input use	-do-	Sampling/survey
Irrigation	-do-	Sampling/survey
3) Livestock		
Availability of feed and fodder	For land use and livestock planning	Data collection and analysis
Livestock breed	-do-	Sampling/survey
Milk production	For economic feasibility	Sampling/survey
Meat production	-do-	Sampling/survey
4) Economic Variables		
Employment (workforce and agricultural laborers)	For sources of income and availability of work	Data collection and analysis
Migration	-do-	Sampling/survey
Income across different landholdings	For land productivity and capacity	Data collection and analysis
Income and consumption	For poverty status	Data collection and analysis
Consumption expenditure	-do-	Sampling/survey
Disposable income on various activities (e.g., clothing, food, shelter, etc.)	-do-	Sampling/survey
Poverty-related indicators	-do-	Sampling/survey
Financial institutions (formal/informal)	For understanding the livelihood opportunities	Sampling/survey
5) Rural infrastructure facilities (roads, market, transport, etc.)	For watershed development plans	Sampling/survey
6) Economic feasibility of improved technologies	-do-	Sampling/survey

9. Image Classification and Change Detection Analysis Using ArcGIS

Whenever, satellite images are available, flora assessment by remotely sensed data will be employed through vegetation indices using ArcGIS following the steps below:

a) Available raw satellite data will be initially corrected and calibrated to remove some errors and deficiencies through image pre-processing.
b) The pre-processing techniques methods that will be applied are: i) geometric correction methods; ii) radiometric correction methods; and iv) atmospheric correction methods.
c) Geometric correction will be done when the images or products derived from the image are used together with other geographic data layers.
d) While radiometric correction will be applied to digital image datasets to ascertain the quality and performance of the sensors. One of the most significant radiometric data activities to be done is the conversion of digital numbers to radiance and reflectance.
e) And the atmospheric correction methods will be done to remove or minimize the effects of scattering in the atmosphere before the energy reaches the earth's surface.
f) After the pre-processing, satellite images can be analyzed to describe the flora or vegetation indices. This is performed by evaluating the wavelengths being absorbed and reflected by the vegetation, where atmospheric water is present. Usually, flora or vegetation absorbs the red and blue wavelengths, reflects the green, strongly reflects the near infrared wavelength and displays strong absorption features in wavelengths where atmospheric water is present. The discussion on the assessment of such variations and relationship should describe the flora or vegetation health, water content, environmental stress and other important related characteristics of the watershed.

Satellite images will also be utilized to account and detect changes on flora or vegetation and climate over time. This will be carried out through the following steps:

a) Acquire thematic information through visual interpretation or computer-based digital image analysis. This will provide the descriptive data about the earth's surface such as soil, vegetation and land cover.

b) Extract metric information using principles of photogrammetry. The information that would be derived are location, height and their derivatives such as area, volume, slope and the like.

And change detection analysis across different periods will be performed using satellite images through ArcGIS to accurately account and detect change in environmental phenomena such as vegetation and climate. This will be done to understand the dynamics of change over the years and predict future trends and scenarios in the area.

10. **Modelling Landslide and Flooding Vulnerability Using ArcGIS Modelbuilder**

A Modelbuilder will be applied to assess the vulnerability of the watershed to landslides and flooding using ArcGIS geospatial processes and techniques.

The Hydrologic Engineering Center-Hydrologic Modelling System (HEC-HMS) rainfall-runoff modelling technique will be utilized to convert precipitation excess to overland flow and channel run-off. Whereas the River Analysis System (HEC-RAS) will be employed to generate unsteady state flow through the river channel network based on the HEC-HMS derived hydrographs.

Refer to the *Training Manual on Watershed Characterization and Vulnerability Assessment Using Geographic Information Systems and Remote Sensing* for reference on the detailed procedure on watershed delineation using hydrology and arc hydro processing tools, image classification and change detection analysis, and modelling landslide and flooding vulnerability.

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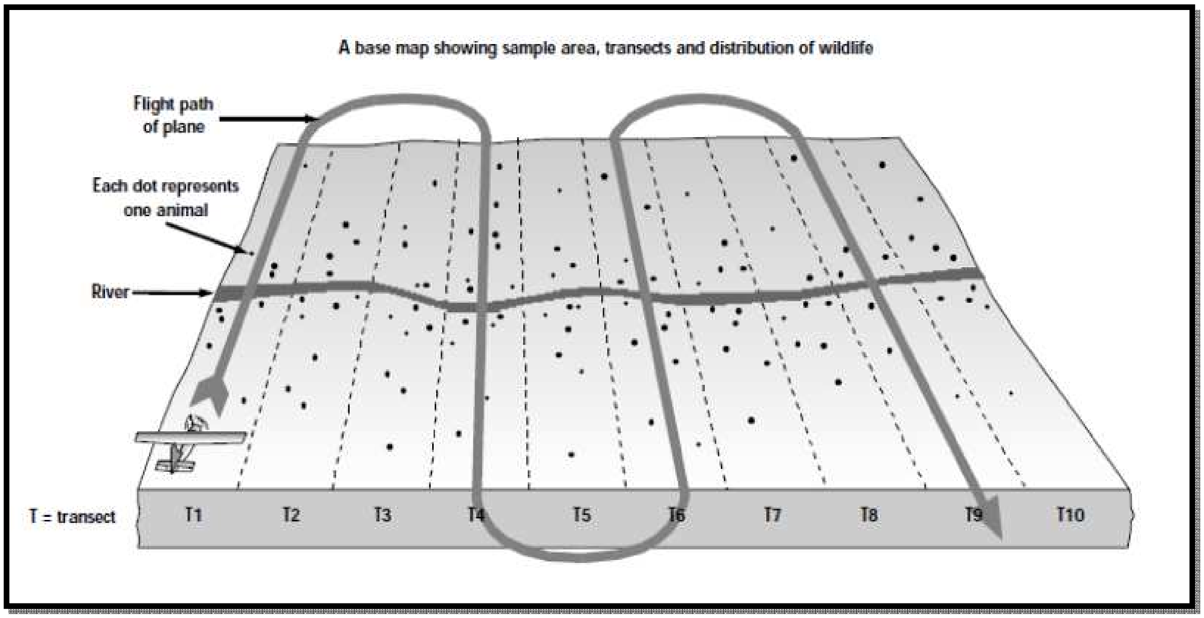

Figure 1. An example of a map showing an area divided into transects or sampling units

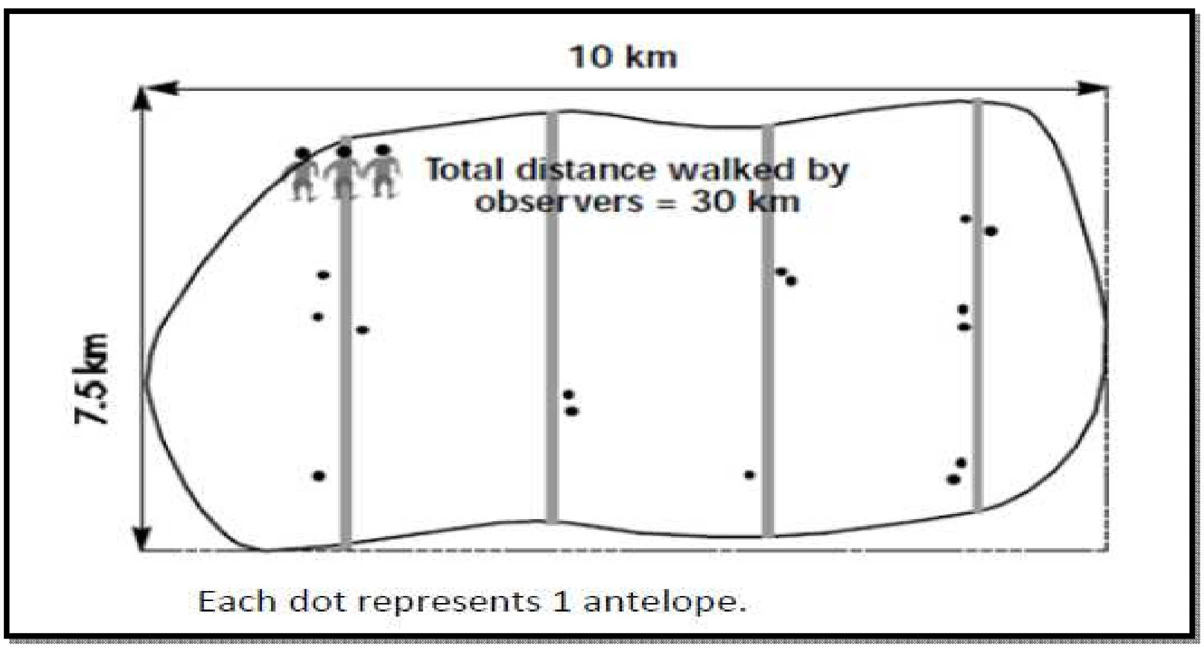

Figure 2. An example of a transect walk method in sampling wildlife in a particular area