LAND RESOURCES INVENTORY IN DEVELOPING COUNTRIES : A PROBLEM OF COLLECTING AND GENERATING RELEVANT DATA

A TYPICAL CASE OF ATMOSPHERIC WATER BALANCE INVENTORY

Tejoyuwono Notohadiprawiro*)

Land Resources Inventory Emphasized

A well documented knowledge about the capability, accessibility and distribution of the country's land based resources is crucial for socioeconomic and sociopolitical development policies, plans and programmes. They provide the criteria of the data base design. A data base is the reflection of the image which an investigator has of "reality" or his perception of it. The main concern of data base design is the identification of objects playing a role in the reality of a field of scientific inquiry and the identification of the characteristics which give the objects distinction. The final aim of data base design is a complete, unambiguous and exact data model, properly describing the part of reality involved in a target information system (Anon., 1984).

Without this knowledge, adequate in amount and informative in form development policies and plans are prone to be met with failure. The Indonesian experience shows how hard it can be to learn a lesson. For proper policy formulation, planning and programming, land resources inventory has to be emphasized. One of the land capability parameters is the atmospheric water balance, expressed as the difference between precipitation and evapotranspiration.

Lack of Relevant Information

One of the many problems developing countries are facing is the lack of relevant data of their land resources. Attempting at closing this gap, governments are carrying out massive census and survey programmes. Surveys which are usually a one time activity can only collect time insensitive data or identify characteristics whose changes with time occur at a geologic time scale so that those changes are immaterial for the data base design (soils, landforms, lithology, major drainage patterns, mineral and organic deposits, etc.). Censuses which are usually taken every five or ten years are useful where the factor time is a monotonous phenomenon (the variable is of a ratio scale type like crop yield, population growth, etc.) or when dealing with absolute scale type variables (number of rice mills, coffee plantations, etc.). But when time is a cyclic phenomenon, or when the purpose is collecting interval scale type data, such as air temperature, rainfall, evapotranspiration potential, etc., surveys and censuses are

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*) Professor of Soil Science, Faculty of Agriculture, Gadjah Mada University, Yogyakarta, Indonesia.

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useless. They must be collected continuously over a sufficient period of time to capture the normal range of value. It needs a station method of data collection in order to obtain a good representation of the condition. For instance, a station method working over a recording period of at least around ten years is required for atmospheric water balance studies.

Simplifying Station Methods To Solve Practical Disadvantages

For developing countries having no long tradition in natural science research, two practical disadvantages of the station method are immediately obvious in connection with data collection. It is time consuming to collect sufficient data and it needs relatively large financing to equip the stations. These countries cannot afford to wait too long before sufficient data become available, and to provide extra budgeting for the many new stations to be built and the old stations to be complemented. Money is also needed for hiring technical personnel to man the stations. While survey and census data are literally heaping rapidly (although the processing is commonly left far behind), station data are accumulating at a much slower rate. Especially lagging is the increase in their area coverage. It is therefore imperative to simplify station methods in the sense of restricting the use of recording instruments to cheaper ones, reducing them in kind, and these in turn will keep wages down as no personnel with special technical skill will be needed. By this way the financial constrain of building additional stations to increase the area coverage can be alleviated. In addition, existing limited equipped stations which were formerly used as minor or supplementary stations, can now be used as major stations so that their long historical records can be fully utilized. This means that in a number of areas there will be no time constraint in increasing the density of stations and obtaining complementary data in order to improve the area coverage.

Enlarging Area Coverage of Potential Evapotranspiration Data

Precipitation (P) and evapotranspiration (ET) are the two parameters of atmospheric water balance (AWB). Together with the soil water balance (SWB), it constitutes the moisture system of an area called moisture regime. A regime depicts a certain condition determining the utility of a site for a definable use. Moisture regime is one of the major land quality determining site condition for agriculture.

P is generally adequately recorded in terms of time span and area coverage. But data on ET are very limited because they need, according to the method used, a set of comparatively expensive instruments to measure, especially the self-recording models. Qualified field technicians to carry out the tedious recording are also lacking. The maintenance of such kind of instruments still seems to be a great bottleneck in scientific work in developing countries.

The Penman method is still considered the best to calculate potential evapotranspiration (ETo) because it yields values very close to that obtained by the open pan method. Conceptually speaking the Penman method has indeed a strong logic base as it involves all pertinent parameters of evapotranspiration, i.e. radiant energy (expressed as day length), kinetic energy of air mass movement (wind speed), heat balance (expressed as air temprature) and air moisture gradient (expressed as relative air humidity). The only disadvantage of this method is technical, particularly for developing countries, that to build enough Penman stations is expensive in terms of manpower and instruments. In the whole of Indonesia there are presently only 91 of such stations, where 47 of them are in Java, 21 in Sumatera, 2 in Kalimantan, 7 in Sulawesi and 14 in the other islands.

There are several methods that can be used to simplify the calculation of ETo, like Thornthwaite, Thornthwaite and Mather, Langbein, Blaney-Criddle, and Turc. Compared to the others, the Blaney-Criddle method is closest in concept to Penman. It uses the same ETo determining parameters as Penman. The difference is that except for air temperature which is measured directly, all of the other parameters are estimated in the Blaney-Criddle method. Furthermore, the B-C format of computation consists of 8 steps only compared to 24 in the Penman format (Doorenbos & Pruitt, 1977). Therefore, the B-C method offers the first option for simplification. There were claims that this method is suitable only for sunny, dry climates. In case of great cloudiness the results are too great (Anon., 1970). Thus the question remains whether it can be satisfactorily applied to cloudy, wet climates like those of the larger part of Indonesia. To a large degree the applicability is also dependent on the reliable estimation of day length, wind speed and relative air humidity.

Test For Blaney-Criddle Applicability

The test was carried out using all available Penman stations by which Penman ETo-s were paired correlated to Blaney-Criddle's. The test stations were divided according to the rainfall characteristics of the area they were in. Three different rainfall areas were recognized based on the average number of dry months in a year (dry month has less than 100 mm rainfall): three months or less (comprising 54 stations), four to six (29 stations) and more than six months (8 stations). Monthly data covering the nine year period of 1971 — 1979 were used.

Six regression types were computed, i.e. linear, exponential, power, quadratic, logarithmic and hyperbolic. Coefficients of determination (R^2) and readiness for prediction and data transformation were the bases of choosing the best and useful fit of regression.

The slightly modified Penman equation was employed (Doorenbos & Pruitt, 1977) :

$$\text{where } ETo = c\,[\underbrace{W.Rn}_{\text{radiation term}} + \underbrace{(1 - W).f(u).(ea - ed)}_{\text{aerodynamic term}}]$$

where ETo = reference crop evapotranspiration in mm.day^{-1}
W = temperature-related weighting factor
Rn = net radiation in equivalent evaporation in mm.day^{-1}
f(u) = wind-related function
ea — ed = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar.
c = adjustment factor to compensate for the effect of day and night weather conditions.

The recommended relationship in Blaney-Criddle method, representing the mean value over the given month, is expressed as (Doorenbos & Pruitt, 1977) :

$$ETo = c\,[\,p\,(0.46\,T + 8)\,]$$

where ETo = reference crop evapotranspiration in mm.day^{-1} for the month considered.
T = mean daily temperature in °C over the month considered
P = mean daily percentage of total annual day time hours for a given month and latitude.
c = adjustment factor which depends on minimum relative humidity, sunshine hours and daytime wind speed estimates.

Relative humidity, daytime hours and daytime wind speed each are estimated by three categories, namely high, medium and low.

Table 1 shows the results of the regression of B-C on PM. In all cases the linear R^2 is always second in order but only slightly less than the highest value. Therefore, the linear regression is preferred over the others. The coefficients of correlation (R) are all highly significant at the 1% level. The Y-intercept of the curves varies with the rainfall type, but the variation in the regression slope is much less. This indicates that the proportionality among station values will not be affected much by the transformations using the different regression equations. Transformation with different regression equations will affect the proportionality among method values.

Table 1. **Coefficients of determination (R^2) and the linearregression of B—C ETo on that of PM**

Average number of dry months	n of pairs	Linear R^2	Type of regression with the highest R^2	Linear regression
3 or less	54	0.813	Power : 0.836	PM = 0.191 + 1.173 B-C
4 — 6	29	0.817	Exp. : 0.823	PM = - 1.221 + 1.554 B-C
more than 6	8	0.703	Power : 0.759	PM = - 1.144 + 1.538 B-C
Indonesia	91	0.811	Exp. : 0.836	PM = - 0.491 + 1.364 B-C

PM = Penman as Y, B-C = Blaney-Criddle as X

For the estimation of daytime hours, relative air humidity and daytime wind speed, the following guide may be suggested (Table 2).

Table 2. **Estimated daytime hours, relative air humidity and daytime wind speed to be used in the B-C ETo computing**

Area	Month	Daytime hours	Relative air humidity	Daytime wind speed
Sumatera	all years round	low	high	medium
Others	1, 2, 3, 11, 12	low	high	medium
Others	4, 5, 6, 7, 8, 9, 10	medium	high	medium

Test For Errors of Transformation

Transformation errors can be introduced by the use of a different regression equation or by an inaccurate estimation of the parameters. Table 3 contains the degree of discrepancy of the transformed Penman values from the original ones using different regression equations for the transformation when applied on the different rainfall areas.

Table 3. **Mean difference between transformed and original Penman values in percent of the original Penman value using different regression equations for the transformation when applied on the different rainfall areas**

Regression equation	Mean differences in percent (a) difference in absolute values (b) difference in actual values			
	all three rainfall areas	high rainfall area	medium rainfall area	low rainfall area
Overall : PM = - 0.491 + 1.364 B-C	(a) 5.14 (b) 0.04	(a) 4.82 (b) - 0.44	(a) 5.28 (b) 0.40	(a) 6.50 (b) 1.66
High rainfall area PM = 0.191 + 1.173 B-C		(a) 4.25 (b) - 0.11		
Medium rainfall area PM = - 1.221 + 1.554 B-C			(a) 5.25 (b) - 0.004	
Low rainfall area PM = - 1.144 + 1.538 B-C				(a) 7.82 (b) - 1.29

The degree of discrepancy is small in terms of absolute values and quite small to negligible in terms of actual values when the + andsigns of the differences are taken into account. The error of transformation is well within the acceptable limit, especially when actual differences are considered. Actual differences are practically canceling each other out. The overall regression equation seems to be generally applicable irrespective of the rainfall characteristics of the area.

The tendency of larger discrepancies in the low rainfall areas may be attributed to the presumably better estimation with the Blaney-Criddle method than with the Penman method. It can be concluded that the very small mean difference in actual value in fact proves that the regional cross picture of the atmospheric water budget can still be undistortedly presented using transformed Penman figures. A stronger proof is provided by the T-test, the results of which are summarized in Table 4. All differences between pairs of original and transformed Penman figures are clearly not significant, as the T_{calc} is always smaller than T_{table} at the 5% level (of course it will be far less at the 1% level), irrespective of the regression equation used.

Table 4. **Paired T-test of the absolute differences among original and transformed Penman's ETo using different regression equations for transformation**

Compared value	**Test area**	**n**	**d mm.day^{-1}**	**T_{calc}**	**T_{table} 5%**	**Statistical inference**
PO — PTI	all three rainfall areas	91	0.244	1.099	1.99	ns
PO — PTI	high rainfall area	54	0.219	1.369	2.007	ns
PO — PTI	medium rainfall area	29	0.261	1.088	2.05	ns
PO — PTI	low rainfall area	8	0.352	0.869	2.36	ns
PO — PTH	high rainfall area	54	0.193	1.156	2.007	ns
PO — PTM	medium rainfall area	29	0.260	1.161	2.05	ns
PO — PTL	low rainfall area	8	0.423	1.351	2.36	ns

d = means absolute difference. PO = original Penman. PTI = transformed Penman using the overall regression equation for Indonesia. PTH = transformed Penman using the regression equation for high rainfall areas. PTM = ditto for medium rainfall areas. PTL = ditto for low rainfall areas. ns = not significant.

One thing that still remains to be proved is the reliability of estimation of the Blaney-Criddle parameters suggested in Table 2. Again the paired T-test will do it. As Sumatera is somewhat different from the rest of Indonesia, it was tested separately using its 21 available complete stations. The other 70 complete stations were used to test the rest of Indonesia. The Blaney-Criddle ETo each station was determinded twice, first by using the measured values of the parameters, and second by using the estimated values. The population of differences between these two values of ETo was then tested for any significance. Table 5 summarizes the results. The differences are clearly not significant, meaning that the estimation of the three parameters presented in Table 2 is adequate.

Tale 5. **Paired T-test of the absolute differences among measured and estimated Blaney-Criddle's ETo**

Area	n	$\bar{x}$ mm.day^{-1}	$\bar{d}$ mm.day^{-1}	T_{calc}	T_{table} 5%	Statistical inference	$\bar{d}$ in % of $\bar{x}$
Sumatera	21	3.6	0.25	1.563	2.09	ns	7.01
Rest of Indonesia	70	3.9	0.323	1.418	2.00	ns	8.22

$\bar{x}$ = mean measured Blaney-Criddle. $\bar{d}$ = mean absolute difference ns = not significant.

Significance of Data Simulation

This presentation is just one example of what can be done to fill blanks of data. By the proposed data simulation method the number of ETo gauging stations in Indonesia can be increased from 91 to 205, an increase of 2.25 times. The distribution is as follows : Sumatera from 21 to 46, Java from 47 to 85, Kalimantan from 2 to 24, Sulawesi from 7 to 24, Southeastern islands from 2 to 9, Irian Jaya from 7 to 9, Bali from 1 to 4, while the number in the Maluku Archipelago remains 4.

With a good data model, supported by well grounded data simulation routines for access to computer services, land resources inventory in developing countries will be much less complicated than it used to be. More data of better quality will be available so that information becomes more communicative. Consequently, station methods become an integral part of the inventory system together with the more familiar methods of survey and census.

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