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Physical Land Suitability Assessment Based On FAO Framework

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Abstract: - The land should be evaluated broadly based on physical and environmental condition. This paper provides the user with a flexible method to evaluate the land based on FAO framework (1976). The method presented in the FAO (1976) is used to provide the physical suitability assessment. The framework was adapted to suit the Malaysian agricultural requirements focusing particularly on mango cultivation in Terengganu as a practical case study. The selection of land qualities and land characteristics were pursued by carefully considering the available data, texts, and literature. Three criteria were used to select the land qualities, which are the effects of land quality upon use, occurrence of critical values for the land quality within the study area and the practicability of obtaining information on the land quality. The land suitability classification will be determined by overlaying thematic maps and by analyzing attribute data using GIS. The study clearly showed the spatial distribution of mango suitability scales.

Keywords: - *FAO, GIS, Suitability, Spatial, Soil.*

I. INTRODUCTION.

Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of landuse [1,2,3]. Physical land evaluation indicates to the degree of suitability for a landuse, without respect to economic conditions. It emphasizes of the relatively permanent aspects of suitability, such as climate and soil conditions, rather than changeable ones, such as prices[4]. FAO framework a universally accepted and systematic standard for land suitability assessment [5,6]. The framework indicates the physical suitability for individual crops. Furthermore, the land is defined broadly in the system and not only by soil characteristics. In the process of land suitability evaluation, components of land unit and inquiries on landuse for each agricultural crop are input data of this process; spatial allocation, boundary, area and scale of each suitability level for each crop are output data of land evaluation process. [7,8]If a land unit is rated physically unsuitable (in the highest-numbered physical suitability class), it will not be evaluated economically; it is ranked automatically in FAO suitability class 'N2' (permanently unsuitable under the assumptions of the landused type). For land that is not completely unsuitable, a physical evaluation can be used to divide the land into degrees of suitability, based purely on physical conditions. The advantage is that physical suitability doesn't change quickly. A physical evaluation can also be used to divide the land units into management groups. In this case, the physical suitability subclass designation shows the relative severity of the various limitations to use, and their type [9].The land suitability classification is determined by overlaying thematic maps and by analyzing attribute data using Geographical Information System (GIS). Moreover the surface and overlay analysis capabilities in GIS can effectively facilitate in handling vast amount of spatial information [10]. The powerful query, analysis and integration mechanism of GIS makes it an ideal scientific tool to analyze it for landuse planning. Management of agricultural resources based on their potential and limitation is essential for development of land and other resources on sustainable basis.The building of a GIS is a chain of operations that leads us from planning data observation and collection, to their storage and analysis, to the use of the derived information in some decision making process [11]. Determination of optimum landuse type for an area involves integration of data from various sources such as soil and metrology. All these major streams can be considered as criteria. Agriculture land suitability assessment in a Geographic Information System (GIS) environment is formulated as a Multi-Criteria Decision Making (MCDM) problem. Multi Criteria Evaluation (MCE) is a transparent way of systematically collecting and processing objective information, and expressing and communicating subjective judgments concerning choice from a set of alternatives affecting several stakeholders. Such systematic, rational and transparent judgments most probably lead to more effective and efficient decisions by individuals or groups of decision makers [12]. The main goal of MCE is to generate a gauge to compare possible alternatives or solutions. Decisions have to be taken at various levels starting from selecting the land utilization types or crops till the allocation of the land utilization types or crops for areas that suit best [13]. This process helps the planner to confine his choices between a set of alternatives, and is often used in land suitability evaluation of alternatives like S1, S2, S3, N1 and N2. Such methods integrate multiple criteria in order to combine all the relevant concerns in the decision problem as a gauge for comparison [14]. Therefore, Multi Criteria analysis can be used to define the most suitable areas for agricultural crops.

II. MATERIAL AND METHOD

In this methodology, the FAO framework for land evaluation (1976) was selected as the main framework for land evaluation. Some modifications to the framework was implemented to suit the local environmental conditions of the study area. The modifications were based on expert knowledge and the cultivation history of the study area. Qualitative classification was used to produce land potential suitability that describes relative suitability in qualitative terms only without any precise calculation of cost. The FAO framework is based upon a philosophy which involves matching the requirements of each land utilization type with the available land resources [15]. Land resources were described as land qualities and land characteristics. Soil data, climate and topographic were prepared in order to create a land information system. The land suitability model were created and integrated in GIS environment as information layers and then overlaid to produce overall land suitability for mango crop. The flowchart of the methodology is presented in Fig. 1

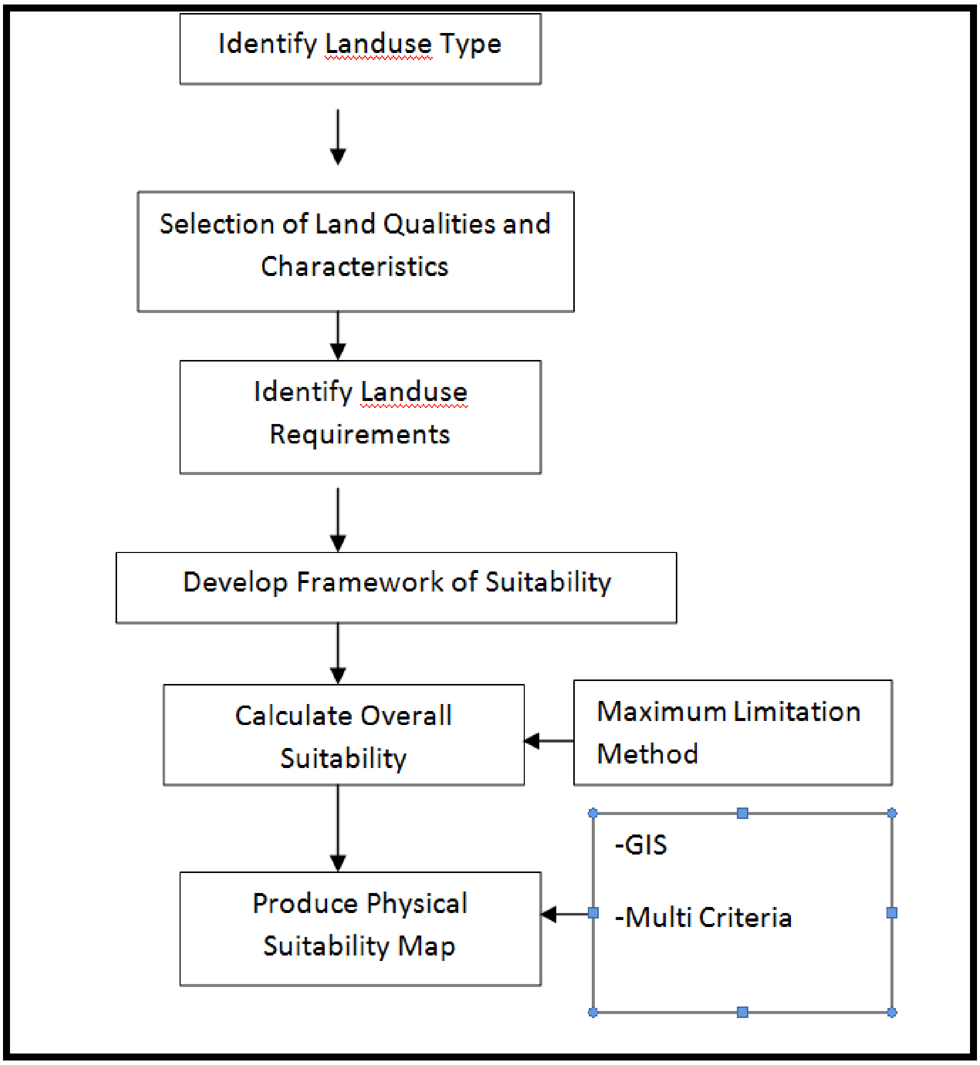

Fig. 1 Flowchart of Methodology

II.1 STUDY AREA AND DATA SOURCE

This study was conducted in the State of Terengganu, West Malaysia. Terengganu is located at the east coast of Peninsular Malaysia, It is located between latitudes 05°51′ 06″ N and 03°55′ 37″ N and longitudes 102° 21′ 11″ E and 103° 31′ 28″ E. Terengganu has a population of 1,080,286. Agriculture remains one of the important activities, with mango, banana, rambutan, durian, watermelon, and various other fruits and vegetables. Different data source were used to conduct the analysis. The data are summarized it in Table 1.

Table 1: List of data sets used in the study

Type of Data	Description	Source
Soil chemical and physical values	Profile data for each type of soil	1992-2006 Department of Agriculture (DOA) Kuala Lumpur
Soil map	Soil semi detail map, scale 1: 25000	2006 DOA Kuala Lumpur
Terrain	The terrain value extracted from the topographic map for each soil type	2006 DOA Kuala Lumpur
Rainfall precipitation	Monthly rainfall from 34 stations during 10 years	1996-2006 Department of Irrigation and Drainage (DID)
Length of dry season map	Scale 1: 50000	2006 DOA Kuala Lumpur

II.2 IDENTIFYING LANDUSE TYPE

Mango is one of the most popular commercial fruits produced in Malaysia. This study deals with its production activities in Terengganu as a practical case. The specific details of mango agriculture landuse information were collected from DOA and shown in Table 2.

Table 2: The specific details of mango plantation landuse in Terengganu (DOA, 2009)

Attribute	Description
Level of inputs	High (high yielding cultivars including optimum fertilizer, application,
Produce and producti	Mango
Market orientation	Commercial
Capital intensity	High
Labor intensity	Low
Mechanization	Motor-driven machinery
Infrastructure	Market accessibility essential. High level of advisory services and application of research findings.
Land tenure	State farms owned and operated by government
Water inputs	Carefully controlled irrigation, water pumped from the agricultural reservoir in the area

II.3 SELECTION OF LAND QUALITIES AND CHARACTERSTICES

Land qualities can be measured from land attributes or land characteristics. Suitability assessment for a landuse type involves four processes [16,17,18]The FAO Framework (1976, 1983) lists 25 land qualities that affect suitability for crops and with many hundreds of land characteristics. Three groups of land use requirements can be identified, which are: physiological requirement, management requirement and conservation requirement. Table 3 lists the land qualities that are considered for land suitability assessment, as suggested by FAO. Some of these land qualities are only applicable for certain crops or certain areas, therefore the land qualities that need to be considered in one evaluation will often be 14 or less

In this research, land qualities proposed by FAO (1976, 1983) were examined against the following three criteria:

i. The effect of land quality upon use
ii. The occurrence of critical value of land quality within the study area
iii. The practicability of obtaining information on individual land qualities

A spreadsheet (see Table 3) was formulated to examine the significance of each land quality. The selection of land qualities based on the effect of land quality upon use, was given a score from 1 to 3, in which 1 is for land quality with significant effect upon land use, 2 for land quality with moderate effect upon land use, and 3 for land quality with slight effect upon land use. The second criterion is the occurrence of critical values within the study area. Three categories were recognized in this criterion: frequent, infrequent, and rare occurrence, which were given scores 1, 2 and 3, respectively. The third criterion is the practicability of obtaining information. These are classified as (a) available (Score 1), (b) not available, but obtainable by research (Score 2) and (c) not obtainable (Score 3). The sheet was filled by experts in DOA. If the score of significance was 1 (important) or 2 (moderately important), then the land quality was taken for analysis; but if the score was 3 (less important), the land quality was omitted. Table 3.5 depicts the required land qualities selected for the study area and their associated land characteristics. They have been aggregated into 3 main groupings (climate, soil, and topographic .Then the criteria that most directly affect crop growth of a particular land utilization type were identified (see Table 4)

Table 3: Selection of land qualities through spreadsheet

Land Qualities	Selection Criteria			
(A) Crop Requirements	Importance f o	Existing critical values in	Availability of data in the	Significance 4
1-Radiation Regime	2	2	3	3
2-Temperature Regime	1	1	2	2
3-Moisture Availability	1	1	1	1
4-Oxygen (soil drainage)	1	1	1	1
5-Nutrient availability	1	1	2	2
6-Nutrient Retention	1	1	1	1
7-Rooting conditions	1	1	1	1
8-Conditions affecting	1	1	1	1
9-Air humidity as affecting	2	3	3	3
10-Conditions for ripening	2	2	3	3
11-Climatic hazards	2	2	3	3
12-Excess of salts	1	1	1	1
13-Soil toxicity	1	1	1	1
14-Pest and diseases	1	1	3	3
(B) Management Requirements				
15-Soil workability	1	2	2	2
16-Potential for mechanization	1	2	2	2
17-Conditions for land preparation	2	2	3	3
18-Conditions affecting storage and	1	2	3	3
19-Conditions affecting timing of	2	2	3	3
20-Access within the production	1	3	3	3
21-Size of potential management units	2	2	3	3
22-Location: existing/ potential accessibility	2	2	3	3
(C) Conservation Requirements				
23-Erosion hazard	1	1	3	3
24-Soil degradation hazard	1	2	3	3
25-Flood hazard	1	2	3	3

Table 4: Land qualities and characteristics in the study area

Grouping	Quality	Characteristics	Unit
Climate	Moisture availability	- Annual precipitation - Length of dry season	mm
Soil	Nutrient availability	- pH H_2O - Depth to sulfuric horizon	 cm
	Nutrient retention	- Soil Organic Matter (SOM) - Cation Exchange Capacity (CEC) - Base Saturation	% % %
	Rooting conditions	Gravel and stones Effective soil depth	% cm
	Soil workability	Texture and structure	%, class
	Oxygen availability (Soil drainage)	Soil drainage class	class
Topographic	Potential for mechanization	Slope	degree

II.4 IDENTIFYING LANDUSE REQUIRMENTS

Climate information was obtained from 32 meteorological stations located within the study area. In general, mango grows in regions with total precipitation between 250 and 6000 mm/year [19]. Mango can withstand a 6-months dry period. Rain during flowering period may depress yields [19]. Slope has a strong effect on the cultivation of crops. As steepness increases, the use of machinery becomes limiting, and establishment and management costs increase as more erosion prevention measures become necessary [20]. In the current study, the terrain value was extracted from the topographic map for each soil type and displayed in GIS layer.Literature on the cultivation crops giving the ideal local conditions are not commonly available[21]. Therefore in this study, cultivation history, local and worldwide knowledge were brought together to identify the best prediction for landuse requirements. Land characteristics and their threshold values were defined considering the optimum requirements of mango. The data and information on the threshold values available from literature and trials from the local studies were used for this study. Table 4 lists the mango requirements derived from the published literature.

II.5 CALCULATING OVERALL SAUITABILITY

The overall physical suitability of land is for LUT is taken from the most limiting land quality (LQ) whose rating is the worst). The advantage of this method is that it is simple and severity levels of LQs are defined according to a standard set of yield reductions. In general FAO practice, S1 corresponds to 85-100% of optimum yield, S2 to 60-85%, S3 to 40-60%, N1 to 25-40% and N2 to 25-0%.The overall land suitability class for mango was determined and assigned to each soil type. Numerically, these classes are assigned with values of 1, 2, 3, 4, and 5, respectively as in Table 5.These are divisions of suitability classes which indicate not only the degree of suitability (as in the suitability class) but also the nature of the limitations that make the land less than completely suitable. e.g. 'S3d': marginally suitable ('S3') because of drainage ('d').Finally, soil, climate, and slope layers were integrated in a GIS environment. Overlay analysis was applied easily to produce mango suitability layer.

Table 4: Mango requirements collected from various published works in the literature

Layer	Climatic Characteristic	Degree of Limitation					
		S1 100 95	85	S2 60	S3 40	N1 25	N2 0
Climate	Annual precipitate (mm) Length of the dry season (months) (P < ½ PET)	>2000 4 - 5	2000-1000 5-6 4-3	<1000-500 6-7 3-2	<500-250 7-8 2-1		<250 >8 <1
Topography	Slope (degree)	0-2	>2-6	>6-12	>12-20	>20-25	>25
Soil	Texture/ Structure	No limitation	No limitation	T1 T3	T2 T4		
	T2: Coarse to moderately coarse textured and weakly structured are indicated, T3: Fine textured and structureless to strongly coarse structured are indicated T4: Fine to moderately fine textures and weakly structures are denoted No Limitation: Fine texture and well developed structure						
	CEC (cmol(+)/kg soil)	>4	4 -2.8	<2.8-1.6	<1.6		
	Base saturation	>50	50-35	<35-20	<20	-	
	pH H_2O Depth to sulfuric horizon	6 -6.8 >150	< 6 – 5.5 >6.8 -7.8 150-100	<5.5-5 > 7.8-8 <100-75	>5-4.5 <8-8.2 <75-50	<4.5 <50-25	>8.2 <25
	Organic matter	>3.4	3.4-2.1	<2.1-1.4	<1.4	-	
	Soil depth (cm)	> 150	150-100	<100-75	<75-50	-	<50
	Coarse fragment (vol %)	0-3	>3-15	>15-35	>35-55	-	>55
	Drainage class	7		5-6	3-4	0-1-2 8-9	

Table 5: Soil Suitability Evaluation for each soil type

	AMA	APK	AWG	BGG	BKU	BKG	BLG	BGL	BMU	BTM	BHM	BLN	BYS
Land Characteristics													
pH (p)	3	4	3	3	1	2	3	4	4	4	4	4	4
Depth to sulfuric horizon (a)	1	1	1	1	1	1	1	1	1	1	1	1	1
CEC	1	1	2	2	1	2	1	1	1	1	1	1	no data
O.M	3	3	2	3	1	1	3	3	3	3	3	3	1
B.S	3	3	3	1	1	3	3	3	3	3	3	3	no data
Coarse fragment (s)	1	1	1	1	1	1	1	1	1	1	1	1	1
Effective depth (c)	1	2	1	1	5	1	2	1	1	5	1	2	1
Texture / Structure (t)	2	2	2	3	2	3	2	3	1	2	2	1	3
Soil Drainage class (d)	3	1	3	4	4	2	1	3	1	1	3	1	4
Land Qualities													
Nutrient Availability	3	4	3	3	1	2	3	4	4	4	4	4	4
Nutrient Retention (n)	3	3	3	3	1	3	3	3	3	3	3	3	1
Rooting Condition	1	2	1	1	5	1	2	1	1	5	1	2	1
Soil Workability	2	2	2	3	2	3	2	3	1	2	2	1	3
Oxygen	3	1	3	4	4	2	1	3	1	1	3	1	4
Current Suitability	3p,n,d	2	3p,n,d	4d/3p,n,t	5c/4d	3n,t	2	4p/3n,t,d	4p/3n	5c/4p/3n	4p/3n,d	4p/3n	4p,d/3t
Nutrient Availability	1.5	2	1.5	1.5	0.5	1	1.5	2	2	2	2	2	2
Nutrient Retention	1.5	1.5	1.5	1.5	0.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.5
Rooting Condition	1	2	1	1	5	1	2	1	1	5	1	2	1
Soil Workability	2	2	2	3	2	3	2	3	1	2	2	1	3
Oxygen	3	1	3	4	4	2	1	3	1	1	3	1	4
Overall Potential Suitability	3d	2	3d	4d/3t	5c/4d	3t	2	3t,d	2	5c	3d	2	4d/3t

III. RESULTS AND DISCUSSION

Since the study area covered more than 100 different soil types, the process of collecting soil data was the most time consuming in this research. In the Department of Agriculture (DOA), there is no systematic database file, all the description of soil was in hard copy in voluminous reports. Fig. 2 shows the results of the endpoint assessment of land suitability for mango based on importance of land conditions and considering the quality of soil characteristics of pH H2O, depth to sulfuric horizon, CEC, base saturation, gravel and stones, effective soil depth, texture and structure and soil drainage class. The suitability classes in the map for each land characteristics were produced based on crop requirements. The overall physical suitability of land was taken from the most limiting land quality (LQ which rated is the worst). The new suitability value was assigned to each soil type. Ranking method was used to classify the soil in raster format.Fig. 3 illustrates the results of the suitability evaluation of mango based on the climatic parameter of dry season months in the study area. The result indicates that all of the covered areas within the metrological station points are considered highly suitable for mango based on crop requirement of annual precipitation. Therefore, dry season is deemed as the critical parameter in the current evaluation.

Fig, 4 illustrates the mapping results of land suitability evaluation based on slope grid (in degrees) showing the effect of topographic parameter on mango cultivation in the study area. From the map, it is noticed that the most suitable area lies in the east of Terengganu State, and the suitability decreases towards the southeast direction.

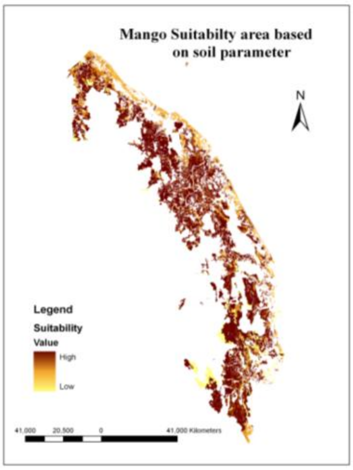

Fig. 2: Suitability map for mango cultivation based on soil parameters

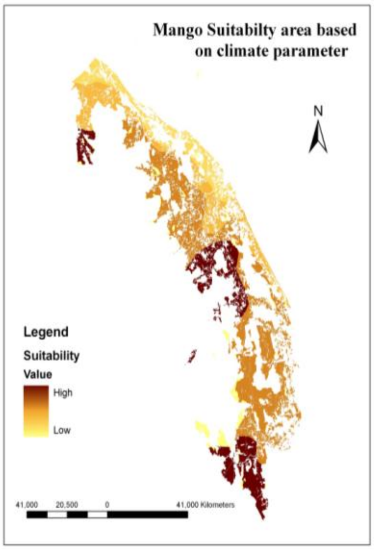

Fig. 3: Suitability map for mango cultivation based on dry season climate

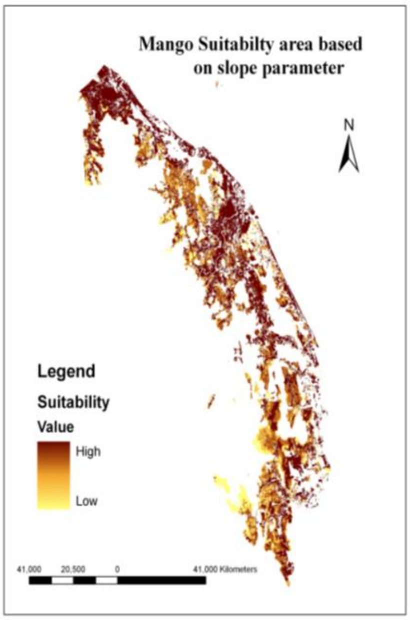

Fig. 4: Suitability map for mango cultivation based on slope parameter

This makes the current classification generally accepted since it evaluates the land by considering physical and environmental factors. The suitable areas for mango cultivation were determined by evaluating climatic, soil and, topographic components. The study clearly showed the spatial distribution of mango suitability scales . The results of the analysis in Fig. 5 indicated that 31% of the study area was identified as the most suitable place for mango (S1), 55% of the area as moderately suitable area (S2), 9% percent as marginally suitable area (S 3) and the remaining portion (5% percent) as not suitable area (N1 and N2).

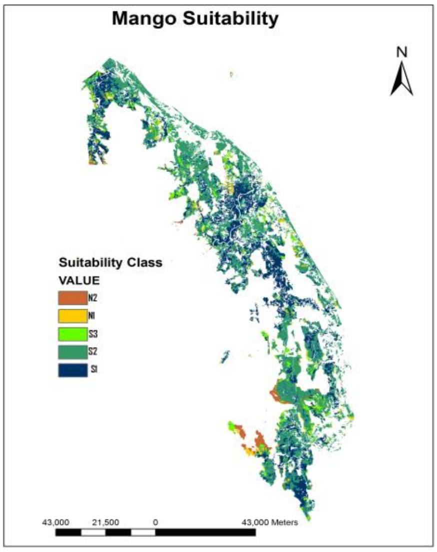

Fig. 5: Mango suitability classes

IV. CONCLUSION

This paper highlighted the need to understand land capacity to support appropriate crop cultivation. It further gives the best suitability classification considering a wide range of multi-disciplinary alternatives. It also identifies land limitation and offers possible land management measures. The development of a land suitability model allows for standardizing a framework for characterizing climate, soil, and topographic conditions relevant to mango crop in the study area of Terengganu. The model identified crop-specific conditions and computed systematically the spatial and temporal data on maximum potential.The ability to integrate data within a GIS is one of the most important features, bringing together data from different sources, formats, and scales and making them compatible with each other and useful for planners, managers, landowners, and the general public

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