Spatial Multi Criteria Decision Making For Coastal Land Management
(Case Study at Maros, South Sulawesi)

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ABSTRACT

Generally, master planning is created to determine areas that are suitable with its land characteristics and capability for specific uses. The process of land suitability classification is the evaluation and grouping of specific areas of land in terms of their suitability for a particular use. This is a complex process involving multiple decisions that may relate to biophysical, socio-economic and institutional/organizational aspects. Coastal management plan is created to achieve sustainable coastal resources uses, and coastal ecosystem protection from disturbance including pollution. It is not easy to maintain sustainable coastal resources, many problems were found to arrange it. One of coastal resources problems is conflict of space/land uses among stakeholders, population, and government in appropriate coastal development activities.

Integration of remote sensing, GIS and spatial multi criteria decision making were used to support coastal master planning for a sustainable coastal management. They are used for classify coastal zoning based on coastal land characteristics and spatial data building and focus to find particularly suitable area for some uses, and identify conflicting area between land suitability and existing landuse and also to develop a coastal master planning using spatial multi criteria decision making for a sustainable coastal management.

Based on the result, Coastal zones in Maros were divided into 2 parts, they are buffer and uses zones, where each area have 343,07 km2 and 572,83 km2 respectively. It means that there is no conservation area, hence all areas is allowed for any uses by still considering environmental aspects. Mostly, fishpond exists in Maros coastal area, but based on land suitability analysis, this area can be converted into tourism area, where it was classified into 2 classes (suitable = 47.988 km2 and marginally suitable = 23.767 km2). In the land, there is conflict of interest between fishpond and resort tourism. Based on this conflict, analysis of policy scenario was needed. Some assessment criteria (economic, sustainable and tourism aspects) have been chosen to determine the best policies/scenarios using multi criteria analysis, and the result showed that alt2b (alternative for tourism development) is the best scenarios for land alternatives.

Key words : Spatial Multi Criteria Decision Making, Land Suitability, RS and GIS

1. INTRODUCTION

1.1. Background

Geographic Information System (GIS) can support spatial analysis, which is often combined with remote sensing technique. The integration of remote sensing and GIS application has long been used in spatial analysis and proven effective and efficient. GIS has the capability to gather and analyze data that are derived from remote sensing results with other data including field data and secondary data as input into GIS spatial analysis, as well as developing coastal master planning.

Generally, master planning is created to determine areas that are suitable with its land characteristics and capability for specific uses. The process of land suitability classification is the evaluation and grouping of specific areas of land in terms of their suitability for a particular use. This is a complex process involving multiple decisions that may relate to biophysical, socio-economic and institutional/organizational aspects. Therefore, multi criteria decision-making is needed to help coastal master planning development. Integration of spatial analysis and multi-criteria decision-making is expected to provide better coastal master planning.

1.3. Objective

Based on the questions above, research objectives are the following:

a. to identify conflicting area between land suitability and existing landuse,
b. to develop a coastal master planning using spatial multi criteria decision making for a sustainable coastal management.

2. METHODOLOGY

2.1. Location

The study area is located in South Sulawesi, Indonesia, approximately between 4° 45' - 5° South and 119° 21' - 119° 42' 30'' East.

2.2. Land Suitability Analysis

There are 4 steps GIS analysis conducted, they are 1) creating land-use classification map, 2) creating matrix of suitability for any activities that will be performed, 3) scoring and weighting, 4) spatial analysis to obtain suitable area for any activities performed.

2.3. Framework of Coastal Development Decision Making

Geography Information System (GIS) and Spatial Multiple Criteria Decision Making (SMCDM) are approaches used to analysis landuse planning by maintaining sustainable development concept. Here, spatial analysis approach/ GIS is more focused on measuring wide location in coastal zone that are suitable for particularly uses. Meanwhile, SMCDM analysis is focused on decision-making that has relevance for ranking of land uses. For analyzing and land use conflict solving in coastal ecosystem can be following procedures.

The conflict map shows certain sustainable area for many activities. That means one location can be used for many land uses. Generally, one area is not used for one activity land suitability only, but it can be used for other activities land suitability.

Conflict map will be overlaid with existing land use map. It is assumed that the permanent existing land use cannot change to other uses (ex: settlement, industry, conservation forest). Therefore, simulation was done for conflict map is only to acquire best land uses recommended by changing certain existing landuse to other uses that are to be developed (aqua/ marine cultivation, tourism and fishing activities).

Policy measure, site selection and autonomous development together lead to the formulation of policy alternatives. A set of measure will determine a combination of activities for each alternative. All other alternatives were developed by selecting those categories in the matrix that can be converted to another land use. The assumptions were made in cooperation with the possibility of land suitability index (Table 2.2).

Table 2.2. Policy alternatives

Alternatives	Description
1.	No change in the present distribution of land use.
Tourism development	
2A	A moderate trend towards tourism development: only the fishponds in areas S1 for tourism are converted: other areas S1 for tourism are converted into tourism.
2B	A strong trend towards tourism: fishpond in areas S1 and S2 for tourism are converted; other areas S1 and S2 for tourism are converted into tourism
2C	A very strong trend towards tourism; fishpond in any area suitable for tourisms are converted; any other area suitable for tourism is converted into tourism.
Marine or Aqua Cultivation	
Fishpond Development:	
3A	A moderate trend towards fishpond development: all areas S1 for fishpond are converted into fishpond culture.
3B	A strong trend towards fishpond: all areas S1 and S2 for fishpond are converted into fishpond.
3C	A very strong trend towards fishpond: any other area suitable for fishpond is converted into fishpond.

Fishing Activities	
4A	If any area not suitable or marginal suitable for any uses are converted in to fishing activities
Sustainable Development	
5A	Tourism (all suitable) on forest: all existing forest will be conserved.
5B	Fishpond (all suitable) on forest: all existing forest will be conserved.
5C	Tourism development on agriculture land: all existing forest will be conserved, agriculture land in any area suitable for tourism is converted to tourism.
5D	Fishpond development on agriculture land: all existing forest will be conserved, agriculture land in any area suitable for fishpond is converted to fishpond.
	Note; 5.c., 5.d., land use changing is only for agriculture land without changing another existing land use. Settlement can not changed

2.9.4. Comparison of Alternatives

The policy alternatives were compared using multi-criteria analysis. In MCA, weighting is the most influential value of criteria to select priority. Input value has function to obtain rank from MCDM processing analysis, and the results are used for coastal land development. The assessment criteria for every land cover category can be seen in Table 2.3.

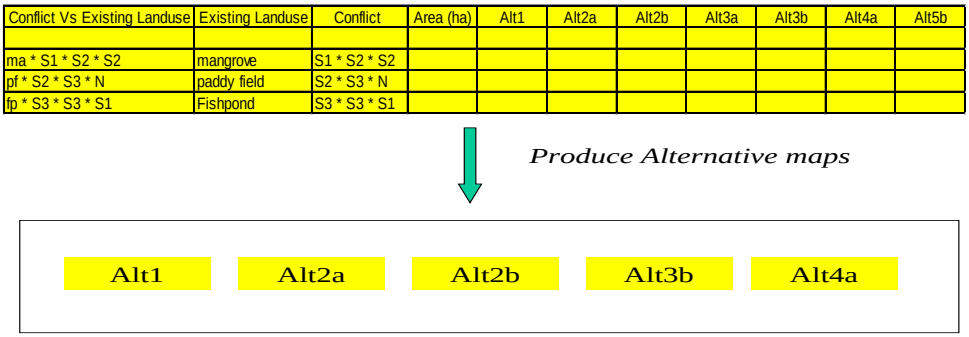


Fig. 2.4. Determining Policy Alternative Maps

Table 2.3. Assessment criteria

No	Policy Objectives	Assessment Criteria	Unit
Land			
1	Tourism Development	Rehabilitation Cost Aesthetic Value	Rp million Ordinal Scale (1 – 5)
2	Sustainable Development	Fertilizer Use Multiple use	Kg Nitrogen/ha/yr Number of Polygon
3	Economic Development	Gross Margin	Rp million/ha/yr
Marine			
1.	Economic Aspect	Investment Benefit	Rp million/ha/yr Rp million/ha/yr

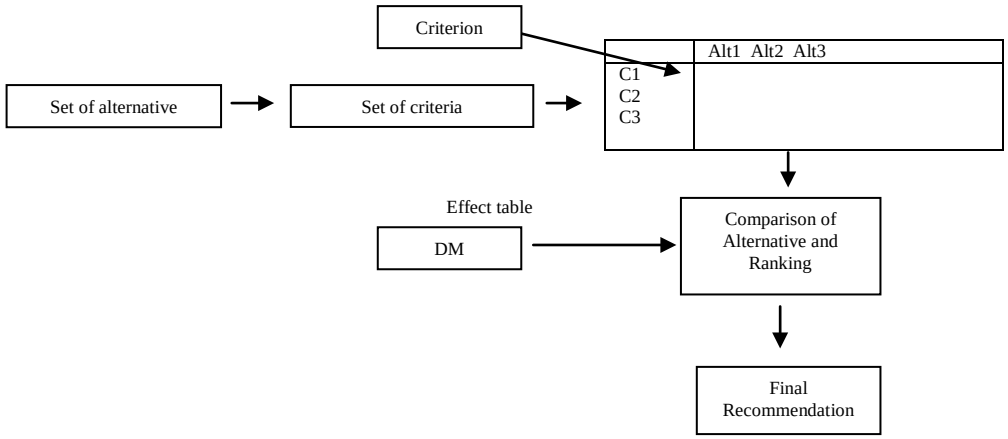
Explanation:

Rehabilitation Cost : The higher the rehabilitation cost, the worse

Fertilizer Use : The higher fertilizer use, the worse
Multiple Use : The more polygon per alternatives, the higher the multiple landuse value (diversity)
Gross Margin : The higher gross margin, the better
Benefit : The higher the gross margin, the better
Aesthetic Value : Total of area per alternative / total of aesthetic value (sum of multiplying each landuse with its ordinal scale)
Investment : The higher investment, the worse
Benefit : The higher benefit, the better

2.9.5. Selection of the Evaluation Criteria

This part determines all alternatives that will be selected to acquire best alternative. To arrange ranks of alternatives coastal ecosystem development, determining criteria/sub criteria that has been appropriate in research location by using MCDM (DEFINITE software) is needed. MCDM/MCA itself is a technique to assist the decision making in selecting from a number of choice alternatives. Relevant criteria have to be identified, analyzed, combined, and evaluated in order to meet specific objectives. Multi criteria methods provide a flexible way of dealing with land allocation decisions.



MCA Flow

3. RESULT AND DISCUSSIONS

3.5. Priority of Coastal Development

Determining priority of activities that to be developed in Maros was based on Multi Criteria Decision Making (MCDM) analysis, also called MCA (Multi Criteria Analysis). In MCDM, weighting is the most influential value of criteria to select priority. For this case, determining weighting will use quantitative analysis based on measuring criteria/sub-criteria assessment selected that is derived from researching and experts. Input/ weighting value entered has function to obtain rank from MCDM processing analysis, and the result will be used for coastal land development.

3.5.1. Land Conflict

The tourism development and fishpond suitability maps were combined to show areas of conflict. The shaded part of Table 3.6 indicates the areas of conflict. There are six (6) conflicting situations occurring in the study area that has an area of 67.727 km2. But, only 40.301 km2 of total area suitable for fishpond and tourism, while 5.431 km2 of the total area is highly suitable for fishpond and suitable for tourism.

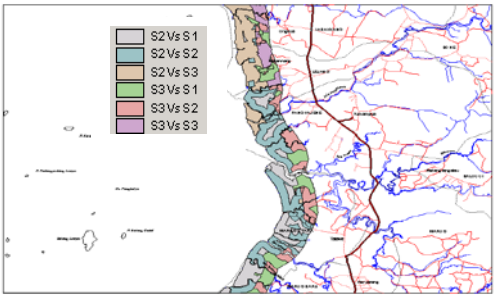


Fig. 3.5. Conflict tourism vs fishpond suitability map

Table 3.6. Conflict matrix for fishpond and tourism suitability (areas in km2)

Tourism	Fishpond			
	S1	S2	S3	Grand Total
S2	5.431	40.301	0.747	46.479
S3	7.548	13.639	0.059	21.248
Grand Total	12.979	53.941	0.806	67.727

3.5.3. Formulation of Policy Alternatives

Policy measure, site selection and autonomous development together lead to the formulation of policy alternatives. A set of measure will determine a combination of activities for each alternative. For the formulation of policy alternatives, the conflict map was crossed (overlaid) with the existing landuse. Areas per landuse category are given in Table 3.8. All other alternatives were developed by selecting those categories in the matrix that can be converted to other land uses.

Table 3.8. Present landuse (areas in km2) for different suitability units for resort tourism and fishpond

	Suitability Rating						
Tourism	S2	S2	S2	S3	S3	S3	Grand Total
Fishpond	S1	S2	S3	S1	S2	S3	
Forest	0.095	0.058	0	0.191	0.777	0	1.121
Agriculture Land	2.598	8.251	0	0	0.344	0	11.193
Settlement	0.131	0.932	0	0.468	1.142	0	2.673
Fishpond	2.607	31.060	0.747	6.889	11.378	0.059	52.740
Grand Total	5.431	40.301	0.747	7.548	13.640	0.059	67.727

Site selection for tourism development : S2 = Suitable, S3 = Marginally Suitable
Site Selection for fishpond : S1 = Highly Suitable, S2 = Suitable, S3 = Marginally Suitable

Making alternative maps based on description of alternatives have already been explained in Table 2.2. Here, policy alternative was divided into 5 groups, they are; no change present landuse (it is still kept the existing landuse), tourism development, aqua cultivation (fishpond), sustainable development and fishing activities. All alternatives were shown in Fig 3.7.

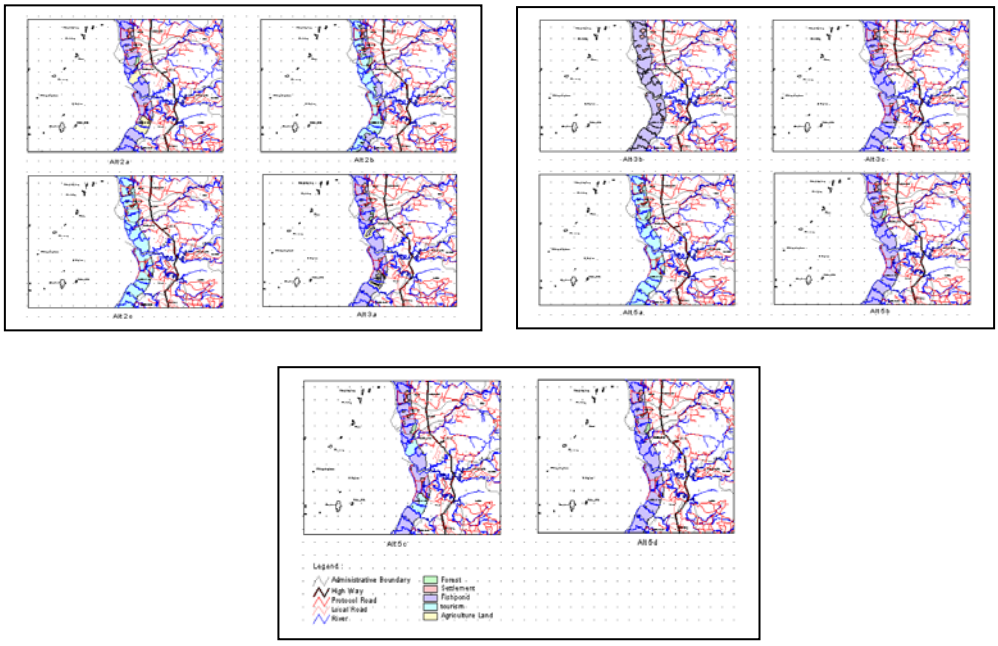


Fig 3.7. Alternatives map

3.5.4. Comparison of Alternatives Using MCA

The policy alternatives were compared using multi-criteria analysis. The pair wise comparison method seems to offer the best possibilities for expressing the variability related to the various policy objectives. Comparisons of all pairs of effects are then converted to quantitative weights for all effects. The outcome of the analysis is an ordinal ranking of the alternatives.

Table 3.10 and Table 3.11 present the dataset submitted to multi criteria analysis. In this "effect table", the different scores (rows) are calculated for each alternative (column). The weighted summation method was used to generate a ranking of the alternatives. As the first step, all effect (criterion) scores were standardized (linear transformation, max/min). Next, an appraisal score was calculated for each alternative by first multiplying the standardized effect score by its appropriate weight, followed by summing the weighted scores of all effects.

Table 3.9. Assessment Criteria

Landuse	Rehabilitation Cost Rp. 10^6/ha	Aesthetic Value Ordinal Scale	Fertilizer Use Kg nitrogen/ha/yr	Gross Margin Rp 10^6/ha/yr
Land				
Forest	0	3	0	0.00702
Agriculture Land	0	2	250	25.74
Settlement	0	0	0	0
Fishpond	0	5	375	12.87
Tourism	20	2	0	40

Source : Joan Loijen, Khairul Jamil and experts

Table 3.10. Effect table for land alternatives

		Alternative				
Criteria (units)	**Unit**	**alt1**	**alt2a**	**alt2b**	**alt2c**	**alt3a**
Tourism Development						
Rehabilitation Cost	Rp (10^6 jt/ha)	0.00	0.00	88296.26	129911.96	0.00
Aesthetic Value	01 - 05 ordinal	4.50	4.50	2.92	2.00	4.63
Sustainable Development						
Fertilizer Use	ton/year	2271.39	2271.39	740.12	0.00	2311.05
Multiple Use	Number of polygon	39.00	39.00	64.00	31.00	48.00
Economic Development						
Gross Margin	Rp (10^6 jt/yr)	95608.69	95608.69	202584.76	259823.91	92202.89

Table 3.10. Effect table for land alternatives

		Alternative					
Criteria (units)	**Unit**	**alt3b**	**alt3c**	**alt5a**	**alt5b**	**alt5c**	**alt5d**
Tourism Development							
Rehabilitation Cost	Rp (10^6 jt/ha)	0.00	0.00	127678.97	0.00	20706.64	0.00
Aesthetic Value	01 - 05 ordinal	4.78	4.78	2.02	4.77	4.49	4.77
Sustainable Development							
Fertilizer Use	ton/year	2351.82	2352.54	0.00	2341.81	2006.01	2341.81
Multiple Use	Number of polygon	45.00	45.00	32.00	44.00	36.00	44.00
Economic Development							
Gross Margin	Rp (10^6 jt/yr)	87915.99	87940.85	255358.73	87572.58	110260.34	87572.48

The criteria were given a priority ranking for the attribution of weights. Various policy schemes were formulated, putting emphasis on tourism development, sustainable development or economic

development. The priority ranking defined for each policy scheme can be strictly applied, with an even spread of weights from first to three ranks or more, according to the relative degree of importance of the criteria. Thus two main policy schemes (TD1 and TD2) were defined for tourism development, two for sustainable development (SD1 and SD2), and two for economic development (ED1 and ED2). Within these main categories, small variants can be simulated, indicating differences in the extent to which one effect is more important than others. Scheme 1 was given equal weights for all effects.

The result of the ranking by the weighted summation method and according to the various policy schemes was given in Table 3.13 and 3.14.

Table 3.12. Priority ranking of effect of policy schemes

Land							
Policy Schemes	Equal	TD 1	TD 2	SD 1	SD 2	ED 1	ED 2
Tourism development	1	1	1	2	2	3	3
Sustainable development	1	2	1	1	1	2	1
Economic Development	1	3	3	3	2	1	1

TD = Tourism Development

SD = Sustainable Development

ED = Economic Development

Table 3.13. Ranking of land alternatives per policy schemes

	Policy Schemes And Weights													
Rank	Equal	Weight	TD1	Weight	TD2	Weight	SD1	Weight	SD2	Weight	ED1	Weight	ED2	Weight
1	Alt2b	0,71	Alt2b	0,62	Alt2b	0,68	Alt2b	0,74	Alt2b	0,76	Alt2c	0,81	Alt2b	0,78
2	Alt5a	0,67	Alt5a	0,56	Alt5a	0,56	Alt5a	0,56	Alt5a	0,60	Alt5a	0,80	Alt2c	0,72
3	Alt2c	0,67	Alt2c	0,56	Alt2c	0,56	Alt2c	0,56	Alt2c	0,60	Alt2b	0,77	Alt5a	0,72
4	Alt3a	0,38	Alt3a	0,44	Alt3a	0,39	Alt3a	0,36	Alt3a	0,33	Alt5c	0,35	Alt3a	0,33
5	Alt1	0,35	Alt1	0,42	Alt3b	0,35	Alt3b	0,31	Alt3b	0,29	Alt3a	0,35	Alt5c	0,31
6	Alt2a	0,35	Alt2a	0,42	Alt3c	0,35	Alt3c	0,31	Alt3c	0,29	Alt1	0,32	Alt3b	0,30
7	Alt3b	0,35	Alt3b	0,40	Alt5b	0,35	Alt5b	0,30	Alt5b	0,28	Alt2a	0,32	Alt3c	0,30
8	Alt3c	0,35	Alt3c	0,40	Alt5d	0,35	Alt5d	0,30	Alt5d	0,28	Alt3c	0,32	Alt5b	0,29
9	ALt5c	0,35	ALt5b	0,40	ALt1	0,35	ALt1	0,28	ALt5c	0,27	ALt3b	0,32	ALt5d	0,29
10	Alt5b	0,35	Alt5d	0,40	Alt2a	0,35	Alt2a	0,28	Alt1	0,26	Alt5b	0,32	Alt1	0,29
11	Alt5d	0,35	Alt5c	0,38	Alt5c	0,32	Alt5c	0,27	Alt2a	0,26	Alt5d	0,32	Alt2a	0,29

As shown in Table 3.13, the first until third level of alternatives considering tourism, sustainable and economic development are not so significant, the criteria almost showed that alt2b, alt5a and alt2c were ranked 1 to 3 respectively. Except for economic development criteria (ED1 and ED2), changing position occurred, where alt2c was positioned on level 1 and 2 respectively, and alt5a was positioned on second level and third respectively. This is because tourism and sustainable criteria were not prioritized.

The advantage of such a spatial presentation in the decision making process is not only to give clear picture of the spatial dimension of the effects of proposed alternatives, but also to illustrate exactly where proposed changes will take place.

3.5.5. Recommended Coastal Landuse Planning

Based on comparison of alternative using MCA analysis, coastal landuse planning can be created by overlaying of the best land alternatives, it is; alt 2b. The map of recommended coastal landuse planning can be seen in Fig 3.8.

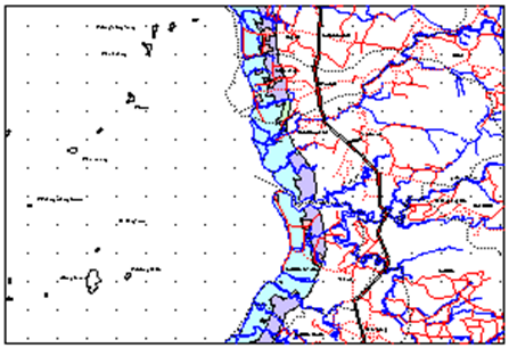


Fig 3.8. Coastal Landuse Planning

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

All research has done and it has inference that:

a. Some of parameters and variables (landuse, marine substrate and mangrove distribution) to determine coastal zones and land suitability can be done using remote sensing approaches, for this case using Landsat TM imagery.
b. Coastal zones in Maros were divided into 2 parts, they are buffer and uses zones, where each area have 343,07 km2 and 572,83 km2 respectively. It means that there is no conservation area, hence all areas are allowed for any uses by still considering environmental aspects.
c. Mostly, fishpond exists in Maros coastal area, but based on land suitability analysis, this area can be converted into tourism area, where it was classified into 2 classes (suitable = 47.988 km2 and marginally suitable = 23.767 km2), especially in marine also showed that almost areas can support tourism activities, because characteristics of marine such as depth and brightness of water are supporting factors.
d. There is conflict of interest between fishpond and resort tourism. Based on this conflict, analysis of policy scenario was needed.
e. Some assessment criteria (economic, sustainable and tourism aspects) have been chosen to determine the best policies/scenarios using multi criteria analysis, and the result showed that alt2b (alternative for tourism development) is the best scenarios for land alternatives.

4.2. Recommendation

All parameters/variables used for land suitability should be standardized before applied to certain area, because one to other area has different characteristics, where some of variables may not be significant if applied in another area. Another reason, all data compiled in location will be better if using time series data to increase data accuracy. Assessment criteria selected may not be completely relevant also. Hence, assessment criteria priority analysis may be required to know how to select important assessment criteria in order to determine the best policies.

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