Application of the GIS Boolean Operations in Evaluating the Conformation of Land-Use Zoning Outcomes: The Case of Jeju Island in Korea

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Abstract: The zoning regulation is provided to restrict the private land-use activities to a certain degree in an effort to augment the level of public welfare. It thus should be based on the principles that are not only logically clear and consistent but, importantly, are free from any defect so as to be objectively agreeable by the majority of the constituents to guarantee the societal equity. The current Korean zoning consequences, however, have been criticized by many for its lack of proper procedures and effective tools to check their aforementioned qualifications. By taking Jeju Island of Korea as the case, this study tries to evaluate the methodology to check the appropriateness of the current zoning outcomes on the GIS platform by adopting specifically the Boolean operations.

Keywords: zoning regulation, Boolean operations, societal equity, conservation and control area

1. Introduction

The zoning practices in Korea are strictly grounded on the actual land uses so that it adheres to the land-use based zoning principles as is commonly exercised in the US and Japan. Though it fundamentally premises the individual freedom in building activities, it nevertheless restricts a part of it for the sake of the public interest if necessary. According to the report submitted by Yoo (2006) to the MOLEG (Korean Ministry of Government Legislation), however, the current Korean zoning regulation is seen to have the following limitations: 1) its time framework is rigid, being subject mostly to the present point in time; 2) it renders a significant equity problem in its zoning processes; and 3) it will inevitably require more zonal categories and/or more subdivisions in the existing ones as the zoning operation expands in the future, possibly causing significant confusions of public concern. Among these problems, this paper tries to delve particularly into the 'equity problem' since the *raison d'etre* of the regulation itself could fundamentally be questioned if its equity base is deemed doubtful at any rate.

In order for the zoning outcomes to be equitable, the logical conformation of the zonal shapes needs to be strictly examined. The inspection of their logical conformation, however, could not readily be performed by simple manual operations since the scope of the current zone categories are not only applicable to the national scale at large, but their structures are also becoming increasingly complicated (Lee, 2008).

This study, in this context, tries to adopt the GIS Boolean operation as one effective tool to automatically check the logical conformation of the zones over the greater spatial range. Among all the zonal categories, the study deals specifically with the 'Control Area (C.A.)' and, further, the 'Conservation and Control Area (C.C.A.)' among its subdivisions—partly due to the data limitation. The C.A. (and its subdivisions) are commonly set to

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restrict the private developments to protect a certain aspect of their valuable environments, *e.g.*, the natural habitats, scenic vistas, underground watersheds, and so on. In actuality, however, many C.A. have been set against its original intention, having been closely related with the chronicle of the disorderly land developments in Korea in its recent history.

2. Study area and data

2.1 Study area

As the southernmost and biggest island in the Korean peninsula, Jeju Island has been geographically free from the administrative influences from other inland districts. Currently endowed with the status of the 'Special Self-Governing Province,' it enjoys relatively higher level of local autonomy than other districts. Likewise, it also reserves more freedom in zoning decisions whereas the zoning in inland counterparts is strictly governed by the national scheme of the 'Urban and Counties Management Plan.'

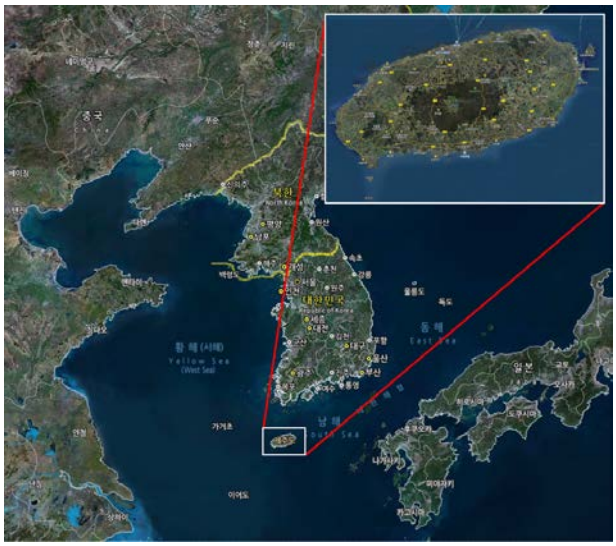

Figure-1 The key map of Jeju Island in Korea

2.2 Data description

The KLIS (Korea Land Information System) database used in this study has been authentically constructed by the MOLIT (Ministry of Land, Infrastructure and Transport) of Korea, and it includes: 1) the Thematic Map; 2) the Parcel Map; and 3) the Land Base Map systems that cover the entire national territory. Among these, the study uses the 'Thematic Map' that comprises the spatial information such as land-uses and zoning, and the 'Land Base Maps' that contains the topographical information such as the elevation of the land masses. In addition, the 'Forest Type Map' of KFS (Korea Forest Service) that is required to satisfy one important criterion to designate the 'Control Area' has also been mobilized for the study.

3. Methodology

3.1 Boolean operation

The rationale to use the Boolean logic in the study instead of the more commonly used fuzzy logic is that: 1) the latter is not adequate for the zonal subdivision; 2) the raw data as well as the criteria adopted in the Juju Island zoning processes are based on the former. The Boolean logic certainly has shortcomings such as: 1) the losses of information; 2) inappropriateness in analyzing the phenomena that are not suitable for dichotomous decision (see, for more detail, Banai, 1993; Oh & Jeong, 2002). Contrary to the expectation, however, these shortcomings could act as the merit in this case since the 'ambiguity' intervened in the determination of the zone boundaries could lead to the inequitable zoning outcomes. Furthermore, the Jeju province government had adopted the dichotomous logic in classifying its C.A.'s at the outset in accordance with the 'Assessment of Land Suitability' prepared by the MOLIT.

3.2 Criteria for the C.A.

The subdivision of the C.A. is subject to the 'Urban Management Plan' by law, and most of the

subdivision practices of the localities are contracted out to the engineering companies. As such, the 'Urban Management Plan of Jeju 2010' (Jeju government, 2002) renders the most authentic list of criteria for Jeju Island's C.A. subdivision. The key principles could be summarized as follows: 1) the Preemptive Planned C.A. (P.P.C.A.) and Preemptive Conservation C.A. (P.C.C.A.) should be sorted out first from the C.A., then, the remainder could be considered as the candidate for the Production C.A. (P.C.A.); 2) in order to reflect the Island's local peculiar circumstances, the areas that satisfy certain indexes of the 'Assessment of Land Suitability' could be substituted with the P.C.C.A.'s by the 'Special Act for Jeju Island Subdivision'; and 3) considering the Island's topographical characteristics, the drainage divides at the elevation of 200m in mid-mountain areas alternate the subdivision criteria for the C.A. The entire settings of C.A. subdivision rules described so far is summarized in Table-1 below.

Table-2 The Jeju C.A. classifications

Altitude	(Below 200m)	(Above 200m)
Preemptive Planned C.A. (P.P.C.A.)	A.L.S.(3rd, 4th, 5th, and +5th Grades)	A.L.S.(4th, 5th, and Preemptive 5th Grades)
Preemptive Conservation and C.A. (P.C.C.A.)	G.C.Z.(2nd Grade), 'Oreum'	E.C.Z.(4-1Grade), F.T.M.(4th Age Grade), G.C.Z.(2nd Grade), 'Oreum'
Production C.A. (P.C.A).	E.C.Z.(4-1Grade), F.T.M.(4th Age Grade), The remainder area	The remainder area

C.A. : Control Area

A.L.S. : Assessment of Land Suitability

F.T.M. : Forest Type Map

G.C.Z. : Groundwater resource Conservation Zone

E.C.Z. : Ecosystem Conservation Zone

L.C.Z. : Landscape Conservation Zone

Oreum : volcanic cone in Jeju language

3.3 Composition of the logical operation

The criteria to subdivide the P.C.C.A. specified in Table-1 could, for instance, be transformed into the following propositions in Table-2 (the 'Oreum,' the volcanic cones, have been excluded since the criteria to define its geographic boundary is not formally prescribed in any legal specs).

Table-1 The proposition for P.C.C.A. subdivision

Proposition 1(A)	The elevation of the area is above 200m.
Proposition 2(E)	The grade of the Ecosystem Conservation Zone (E.C.Z.) in the area is of 4-1.
Proposition 3(F)	The age grade of the Forest Type Map (F.T.M.) in the area is of the 4th.
Proposition 4(U)	The grade of the Groundwater Resource Conservation Zone (G.C.Z.) of the area is of the 2nd.
Proposition 5(W)	The area belongs to a C.A. zone that is subject to subdivision.

Equation 1 expresses theses propositions in one logical form. The logical conjunction, disjunction, and negation can be corresponded by each specific GIS function as exhibited in Table-3. The procedures of entire GIS Boolean operations, then, could be composed as charted in Figure-2.

$$W \wedge ((A \wedge (E \vee F \vee U)) \vee (\neg A \wedge U)) \rightarrow P.C.C.A. \quad \text{(Eq. 1)}$$

Table-3. GIS functions for Boolean operations

Boolean operation	GIS function
X∧Y (AND, Conjunction)	[X] INTERSECT [Y]
X∨Y (OR, Disjunction)	[X] UNION [Y]
¬X (NOT, Negation)	[W] ERASE [X]

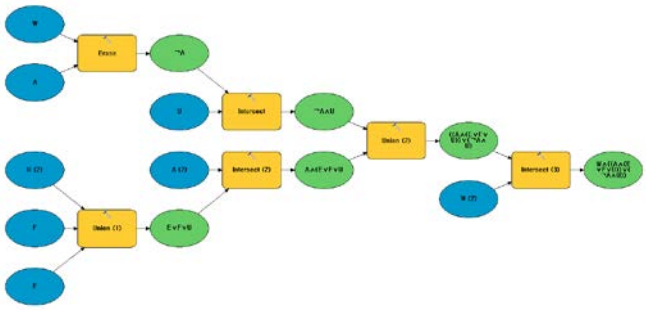

Figure-2 Flow of the operation to decide the P.C.C.A.

3.4 Consequences of operation

Figure-3 compares the consequences of the P.C.C.A. obtained by the GIS Boolean operation with the actual P.C.C.A.'s in Jeju Island. The figure clearly shows that significant incidences of mismatching area (black areas in the upper panel) scatter across the entire island. For more detail, the 'Gotjawal' area has been enlarged into the lower panel, and the mismatching areas (the hatched polygons) are seen to intervene to a substantial degree, crisscrossing amongst different subcategories of the C.A. The level of such discrepancies certainly seem to exceed the plausible level of exceptions that could occur in the real world.

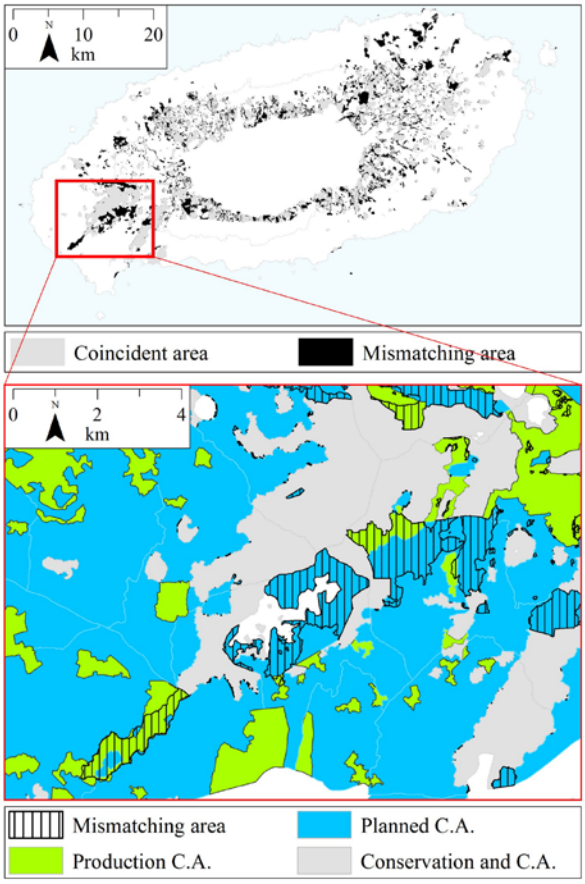

Figure-3 Actual and projected zones of C.A.

4. Conclusion

In an effort to augment the equity consequences of the Korean zoning practices, the study tried to assess the logical conformation of the current zoning outcomes and tested the applicability of the Boolean operations in its process. And it has been found that the method was adequate for the purpose. Logically, however, the overlapping of all the zoning categories can create the number of cases as many as that of the combinations of the entire zoning criteria. And the study dealt only a minute case among them. Furthermore, there truly exist, in reality, some 'ambiguous' areas between the conflicting land-uses that the fuzzy logic approach might be preferred in place of the Boolean one. The extended studies to test such cases and methods yet remain to be challenged further.

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