6.3 Water Quality Comprehensive Evaluation

6.3.1 Concept

Judging whether or not a water source is suitable for a drinking water supply by just comparing the water quality analysis result with the Tanzanian standard or the WHO guideline is too simple. It is not a black or white situation. For example, although a water source may be judged as usable for a drinking water supply, it still remains unclear as to just how safe the water is. For example, the water quality may be just relatively good, although some minor health problems may occur. Furthermore, it is necessary to mention if the water quality is actually near the marginal value of suitability. Such water sources may require some kind of simple treatment in addition to disinfection. In order to solve these problems, an index showing the degree of water quality was created to perform a comprehensive evaluation.

6.3.2 Evaluation Criteria

The items in both the Tanzanian standard and the WHO guideline, can be divided into two groups: common counts and detrimental substances. In the event that not all items of a water source are below the standard value, the priority criteria to evaluate the water quality should be on the basis of items of detrimental substance. Then, the common counts should be examined to ascertain if the water is free of any obstacle for purposes other than drinking. Therefore, in this study, two kinds of criteria are created for the evaluation of detrimental substances and common counts, respectively.

<u>The First Criterion</u>

Based on previous studies and studies in similar areas, the following items have been selected for examination under the first criterion: fluoride (F), sulfate (SO_4), arsenic (As) and nitrate (NO_3). For almost all these items, the value set in the Tanzanian standard is not as strict as the WHO guideline. The value for fluoride in the Tanzanian standard, for example, is five times that in the WHO guideline. Therefore, water will be judged as unsuitable for drinking, if one or more items of the water fail to meet the Tanzanian standard.

On the other hand, even if the water meets the Tanzanian standard, the water quality may still be questionable, if one or more items are over WHO guideline values. And if the water quality is near the Tanzanian standard, the water should just be considered as barely suitable for drinking.

<u>The Second Criterion</u>

The second criterion is used to examine the following items: total iron (Fe), manganese

(Mn) and chloride (Cl). These items generally not pose any health risk; thus, will not be used in judging the suitability of a water source for drinking purposes. This criterion should be applied realistically, especially in the areas where drinking water is deficient and the development of alternative water source is difficult. On the other hand, the possible problems concerning these items need to be pointed out by using these evaluation criteria.

Special Item

The item of total dissolved solids (TDS) is a little different from the items included in the above criteria. Although it would have an impact on taste if the value exceeded the Tanzanian standard, the influence on human's health would be small. According to the results of previous studies based on animal experiments, it seems reasonable to assume that TDS would have hardly any effect on health provided that the TDS value does not exceed 3000mg/ℓ, which is 1.5 times the value in the Tanzanian standard.

At present, several wells and pits are in use for drinking water by villagers in the study area, even though their TDS value is between 2000 and 3000 mg/ℓ. This kind of water source is not rare along the coastline in the eastern part of the study. Local residents do not usual use such water sources for drinking purposes but as there is no alternative for better quality water they are forced to bear the salty taste. Unless better water can be conveyed from other water sources to those villages, residents will have no choice but to continue to drink such water.

However, if the TDS value gets higher, the problem would not only be limited to taste. The villager's health would also be at risk and would have to be evaluated differently from the other items in the second criterion. To evaluate TDS, the minimum salinity value of limitations for good health of mammals is taken from the previous studies. The water is judged as unsuitable for drinking if the TDS is over 3000 mg/ℓ, and it must be pointed out if a water source has a TDS value between 2000 and 3000mg/ℓ, even though it may be used for drinking purposes.

6.3.3 Factors

The First Criterion

Under this criterion, the water source will be judged as unsuitable if the Tanzanian standard is exceeded, and the evaluation value will be 0 (zero).

If the item is between the WHO guideline value and the Tanzanian standard, it will be given an evaluation value between 0 and 1, given by the following formula.

$$ES1 = 1 - ((ASR-STD_{WHO})/(STD_{TZ}- STD_{WHO}))^2$$

ES1: evaluation value for criteria 1

ASR: water analysis result

STD_{WHO}*: WHO guideline value*

STD_{TZ} *: Tanzanian standard value*

The Second Criterion

Items in the second criterion will get an evaluation value of 1(one), if it meets the Tanzanian standard. If the item exceeds the Tanzanian standard, it will not lead to a judgment of unsuitability, but will be evaluated by the following formula.

$$ES2 = 0.5 + STD_{TZ} / (ASR \times 2)$$

ES2: evaluation value for criteria 2

Special Item

TDS is the only special item in this study. Since TDS should be fundamentally considered as a health related item, the evaluation was applied on the basis of the method for the first criteria. However, the factor 3000 mg/ℓ was used in the evaluation formula instead of the STDTZ.

Comprehensive evaluation value

The comprehensive evaluation value (EST) has to be a function of all items included in all criteria, and to satisfy the following requirements:

If one or more than one item is evaluated as 0 (zero), EST is 0.

- Only when all items are evaluated as 1(one), can EST get the highest value 1.
- If one or more than one item gets an evaluation value between 0 and 1, EST will be equal to or smaller than the smallest one of all single items, but will not be put at 0. In this case the contribution of each items to EST will be in the order just opposite the order of the evaluation value. That is, the smaller the evaluation value is, the larger influence it will have on the EST.

The formula used in this study for calculating the EST is given as follows:

$$EST = (ET_1) \times (ET_2)^{1/2} \times \cdots \times (ET_{i-1})^{1/(i-1)} \times (ET_i)^{1/i}$$

ET_i *: evaluation value of ith item in sequence from small to big.*

6.3.4 Comprehensive Evaluation

Figure 6-9 shows the result of the comprehensive evaluation (EST) of water quality by the first criterion. The result is divided into 12 grades from 0 to 1. The area with an evaluation value of 0 is colored in black to indicate the water quality there is unsuitable for a drinking water supply.

Groundwater with EST near 0 is not judged as a disqualification, but attention has to be paid to this because the very small EST indicates that some detrimental substance in the groundwater is near the critical point. If water of that quality were used, it would be necessary to carry out the monitoring of water quality and to attach caution not to drink too much.

The area with an EST approaching 1 shows good water quality, because all items concerning detrimental substance do not only meet the Tanzanian standard, but also nearly satisfy the corresponding values in the WHO guideline.

Figure 6-10 shows the result of EST by the second criteria. Since items included in this criteria have little effect on human health, the EST based on this criteria will not disqualify the source for drinking purposes. For any single item in this criteria the evaluation value ES2 would be over 0.5, but the comprehensive evaluation value might be smaller than 0.5, if the Tanzanian standard were significantly exceeded by several items. Even in that case, however, the EST will never be smaller than 0(zero).

The EST in Figure 6-10 ranges from 0.5 to 1, to indicate that no water source in the study area has several items of criteria 2 that largely exceed the Tanzanian standard. No special treatment would be needed in areas with EST value of 1, because that indicates that all items in the second criteria meet the Tanzanian standard. In other areas, however, the smaller the EST value is, the more important it becomes to treat the water before drinking and to attach caution not to drink too much.

Figure 6-11 shows the results of the comprehensive evaluation by all items in all criteria. As in Fig. 6-9, EST is expressed in 12 grades from 1 to 0.

The areas with an EST value of 0, and from 0 to 1 occupy 1.5% and 26.5% of the whole study area, respectively, to indicate that a water quality problem has been identified in about 28% of the study area, within which about 1.5% is so awful that it could not be permitted as a source for drinking water supply.

When water quality is compared by region, the whole area in Mtwara is found to have EST values larger than 0.5, to indicate that there is little problem concerning human health. However, there are some districts like Masasi where the color is light pink or light gray, to indicate the need to treat water before drinking.

In the northwestern part of the Lindi region, Liwale district is found to have relatively good water quality like the Mtwara region. However, groundwater of suspicion as to its effect on human's health is distributed in all other districts in Lindi.

The results of the comprehensive evaluation for all criteria are summarized in Table 6-5.

Table 6-5 Summary of Comprehensive Water Quality Evaluation

Rank	Rank 1 Standard				Rank 2 Standard			Other
Item	F	As	SO_4	NO_3	Fe	Mn	Cl	TDS
Minimum	0.99	1	0	1	0.57	0.58	0.84	0.09
% of Area of Black*	0	0	1.4	0	0	0	0	0
% of Area of OC**	0.15	0	2.7	0	9.3	4.5	0.5	16.8

% of Area of Black*: percentage of area with EST value of 0.

% of Area of OC**: percentage of area with EST value between 0.and 1.

In the process of the comprehensive evaluation, the evaluation value was calculated for each sampling point by directly using the water quality analysis results. The interpolating between sampling points was carried out by the Kriging method, which is the most widely used in geological statistics. Accuracy of the process, therefore, depends on the identity of data used for zoning.

However, some important data, such as well depth, the installation depth of the strainer, the existence of sealing, and the characteristic of the aquifer are insufficient. Therefore, there remains some possibility of the problem concerning the uniqueness of the results of the comprehensive evaluation.

In spite of the same sampling point, the water quality might be largely different between dug wells and boreholes. A significant difference can also be found between two boreholes, even though they are separated by only several tens of meters. In such cases, the sample with relatively poor water quality was used for evaluation to ensure safety for the drinking water supply.

Therefore, the evaluation result has to be interpreted exactly as follows: the result shows the highest probability for water quality to appear there. It is certainly that the water quality might be found to be different from the evaluation results, if the groundwater were extracted from wells with a depth different from the well used in the evaluation.

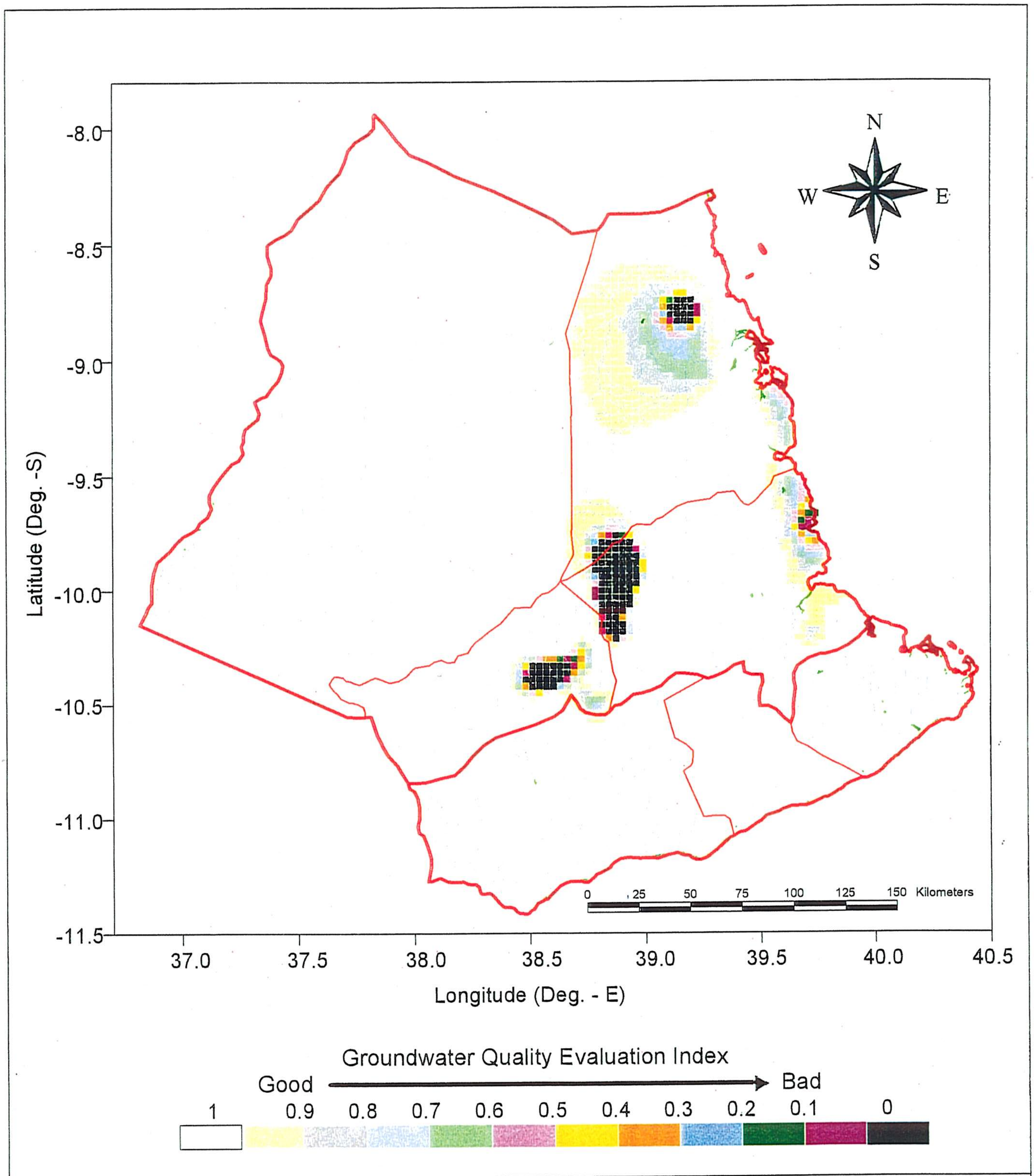

Fig. 6-9	Groundwater Quality Evaluanted by Standard of Detrimental Substance (2000)

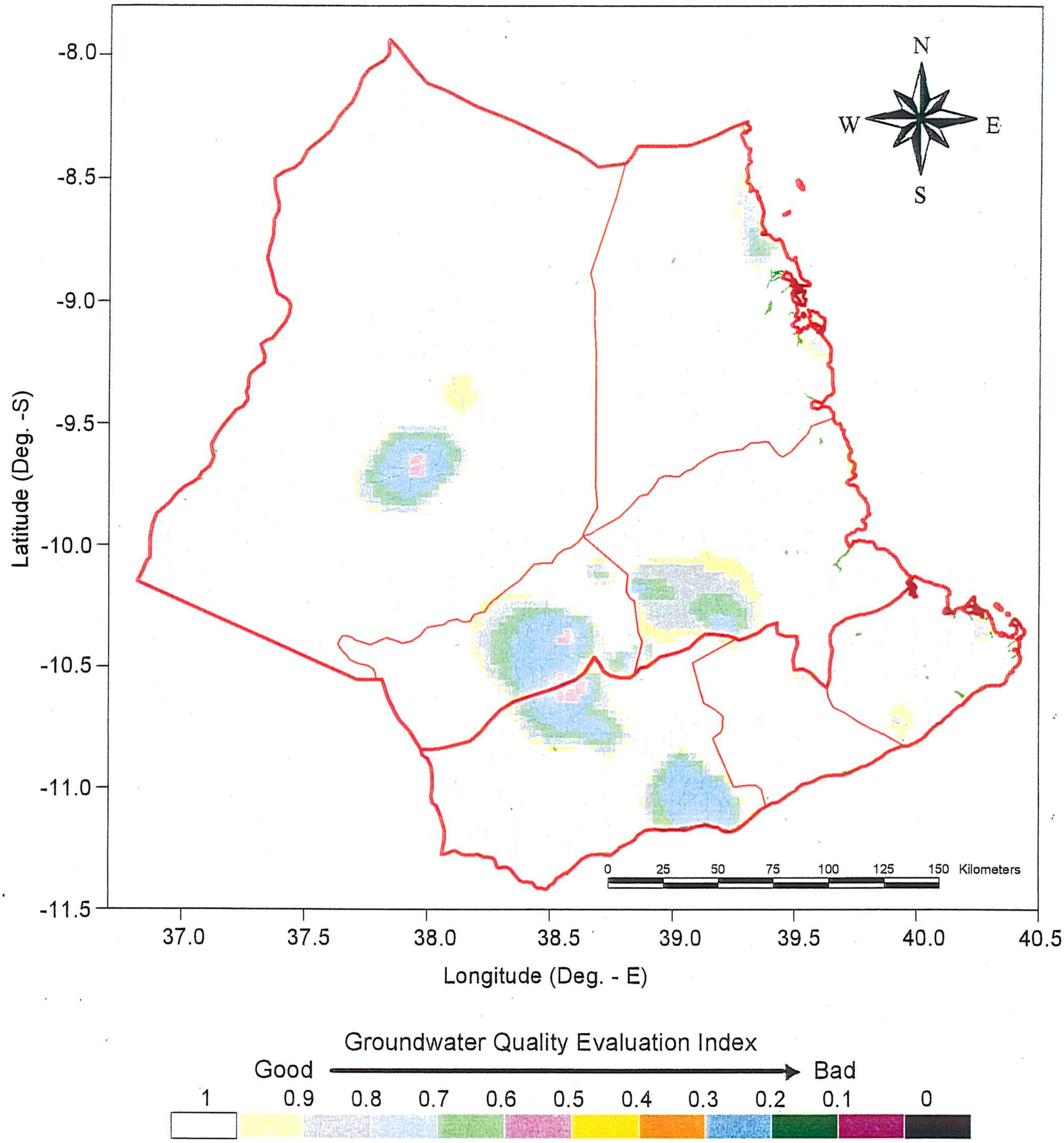

Fig. 6-10	Groundwater Quality Evluated by Standard of Common Counts (2000)

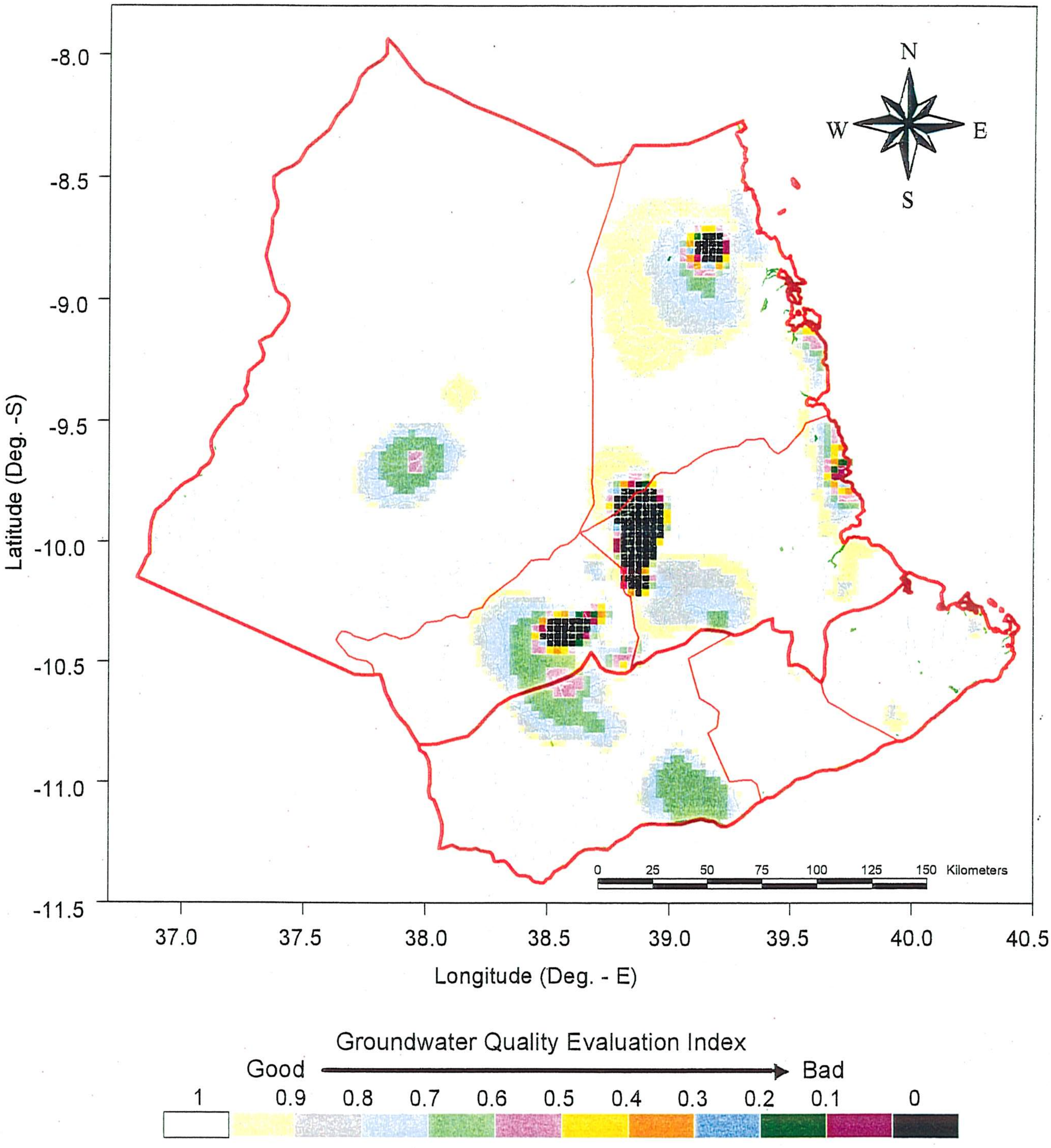

Fig. 6-11	Comprehensive Evaluation of Groundwater Quality in the Study Area (2000)