(1) Damage to Irrigation Intakes

a) K. Progo

Actual damage which has occured to these intakes of K. Progo is listed below:

Jati Intake:

Year of Construction: 1973

Irrigation Area: 400ha.

Suffered a heavy in-flow and deposit of silt. Maintenance by annual excavation requiring 500 workers over 5 days.

Sapon Intake:

Found at present in good working order

The existing intake was built in 1969. Before then, it was located at Bakalan about 1.5km downstream from the present location.

The Bakalan Intake suffered was destroyed by heavy lateral erosion (about 40m-wide) in the flood of 1969.

Kamijoro Intake:

Year of Construction: 1924

Several years after completion, totally buried under silt.

Makam Bulan Intake:

Year of Construction: 1927

Cannot function usefully due to heavy silt deposits

Mangir Intake:

Year of Construction: 1965

Intake from the main river by an open cut channel

To date, this intake properly fulfills its function

b) K. Opak

The intakes of K. Opak consist of six full transverse weirs and six of lateral intakes.

All intakes, including Blawong and Canden, which were completed in 1977, are located at points more than 10km up from the estuary. Although the intakes are filled with silt, they still functions properly.

The side type intakes are closed and their functions temporarily suspended during the wet season to avoid intrusion of silt. The bottom of the intakes are located about 0.5m about the river-bed.

Since stream flow is rather meager and the bottom of the intakes are located above the river-bed, temporary full transverse weirs (approx. construction cost: Rp 1,000,000.-) are used as water intakes during the dry season. Bamboo, banana leaves and sand are used for the construction of the temporary weirs which are usually flushed away by floods in the following wet season.

c) Damage to Intake

It is necessary to maintain the bottom of the intakes as close as possible to the surface of the river-bed. This makes maintenance extremely difficult where the river-bed variation is violent, especially from silt deposits.

(2) Landside Water Inundation

a) K. Progo

Besides inundation caused by river water, inundation by landside water was observed particularly in the neighborhood of the estuary.

On the right bank, floods were reported along the K. Galur flowing into the main river in the neighborhood of the estuary.

The estuary of the main river is almost always blocked up during the dry season. The discharge of the main river, which is low in the dry season, flows into the channel of the K. Galur, a tributary, which then flows into the main river at the point close to the estuary. Backwater forms due to poor drainage and inundation over the area along the tributary. At present, the backwater from the main river is automatically controlled by a wooden balance gate. The gate was used for the control of inland and the main river water; however, the operation of the gate deteriorated and is further hampered by the growth of aquatic plants in the well nourished water of the protected lowland along the K. Galur.

A similar situation is also generally true of the right bank area where inundation is caused by the K. Trihudati, a tributary joining the main river in the neighborhood of the estuary. In this case, too, a gate with a wooden balance controls the water level of the inner and outer sides of the gate.

Additional efforts to improve the administration and maintenance of the gates are highly recommended.

b) K. Opak

No significant damage caused by the inland water inundation was reported, however, as the estuary block-up become more prominent in the dry season, problems will most likely occur.

(3) Estuary Block-up

The estuaries of both the K. Progo and K. Opak are usually blocked up during the dry season by a tremendous volume of silt and debris transported by floods during the preceeding wet season because of tidal flow caused by high westerly sea winds and meager stream flow during the dry season. Excavation by manual labor is required now to eliminate the problems of inundation caused by the inland water.

(4) Lateral Erosion of River Bank

Heavy damage on the river banks was caused by a lateral erosion in several places. In the flood of March 1969, wash-out of the intakes and losses of farmland resulted from lateral erosion, about 40m in length, at the point about 10km upstream in the estuary of the K. Progo.

In summary, the above-mentioned problems at various spots along the river channel have the following main causes:

a) A huge volume of sediment discharge from upstream

b) River-bed evolution and unstable channel gradient

c) Fine granulation of river-bed materials

d) Unsteady meandering river characteristics

e) Considerable differences in discharge between wet and dry seasons

f) The decrease of river maintenance flow due to the integration of irrigation intakes upstream.

g) Lack of proper administration and maintenance of the river structures

h) Strong tidal flows

i) Steep declining slope of coastal seabeds

2.5 Socio-economic Factors

2.5.1 Population

High population density is a measure of the social importance of such areas and the urgent need for disaster prevention measures in them. Based on data collected in a socio-economic survey at the kelurahan level, the rate of population growth is only 0 - 2% per annum for over two-thirds of the density populated kelurahan where the average population density is 1,584 persons/km^2. In nuée ardente hazard areas and Type-1 areas with frequent lahar and benjir damage, the population densities are 576 persons/km^2 and 1,381 persons/km^2 respectively.

When compared with statistics for population density and growth for the whole of Indonesia, the figures for the areas covered by the disaster prevention plan are higher. Comparative figures taken from the U.N. World Statistics Yearbook 1976 edition are listed below:

Area	Density (1975)	Growth Rate (1970-5)
Indonesia as a whole:	71 persons/km^2	2.6% per annum
Central Java:	716 persons/km^2	1.7% per annum

Table 2.5.1 Area, Population and Population Density in 1976

Type	No. 05 Kelurahans & M.P.P	Area (km²)	Population	Population Density/km²
Nuee Ardente	26	136	78,298	576
Type I	27	78	107,689	1,381
Type II	50	147	194,978	1,326
Type III	8	71	56,900	801
Type IV	114	414	902,000	2,179
Total	225	846	1,339,865	1,584

Table 2.5.2 Average Rate of Population Increase from 1966 to 1976

Growth Rate (%) / Type	∿ -3.1	-3.0 ∿ -0.1	0 ∿ 0.9	1.0 ∿ 1.9	2.0 ∿ 2.9	3.0 ∿ 4.9	5.0	Total
Nuee Ardente	-	1	12	7	5	1	-	26
Type I	-	4	12	9	1	1	-	27
Type II	2	13	14	8	3	2	1	43
Type III	-	-	6	1	-	-	-	7
Type IV	5	6	30	34	13	3	3	94
Total	7	24	74	59	22	7	4	197

2.5.2 Land Use

Favorable natural conditions make almost the entire area cultivable. The annual rainfall in the area is 1,500-4,500mm. The land is for the most part gently sloping (70%, 0-3 deg.; 88%, 0-8 deg), and the soil is fertile.

The two main patterns of land-use are farmland (62%) and villages (24%). Approximately 70% of the farmland consists of rice paddies. Depending on irrigation conditions, one harvest of rice and one or two of some other crop are possible. In the rainy season, practically the entire farmland area is devoted to wet rice production.

Land Use

Location	Total Area ha.	Type of Land Use (%)				
		Sawah* (%)	Tegal** (%)	Village (%)	Forest (%)	Others (%)
1. City of Yogyakarta	3,250	20	2	40	-	38
2. Sleman	57,480	48	12	27	2	11
3. Bantul	49,280	37	14	36	1	12
4. Magelang	113,280	37	32	15	6	10
5. Klaten	67,010	53	11	28	2	6
Total	290,300 (100%)	123,903 (43%)	57,482 (20%)	70,315 (24%)	9,779 (3%)	28,820 (10%)

* Sawah : irrigated land suitable for wet rice

** Tegal : dry crop land unsuitable for wet rice

2.5.3 Agriculture

In order to get an idea of future agricultural production and to determine the present and future importance of agriculture in the industrial and employment structures of the area, past official statistics and socio-economic survey results have been used to study the following topics which are discussed in detail in the subsequent paragraphs:

1) Agricultural production stability
2) Land productivity

3) The degree of specialization of agricultural production
4) Present level and tendency of yield of paddy, and
5) The correlation between land productivity and the rate of land utilization.

(1) Stability of Agricultural Production

Wet paddy, soya bean, and sweet potato yields are stable, but those of dry paddy, maize, and cassava are relatively unstable.

(2) Productivity of the Land (crop yield index)

The farmland in the area can be classified into the following four productivity types on the basis of crop yield index numbers for 1971 and 1976:

	Category of Productivity		Relation to Crop Yield Index Number
Class-I.	Low productivity land	:	Less than 100 for both 1971 and 1976
Class-II.	Land with rising productivity	:	Less than 100 in 1971 and over 100 in 1976
Class-III.	Land with declining productivity	:	Over 100 in 1971 and less than 100 in 1976
Class-IV.	High productivity	:	Over 100 in both 1971 and 1976

Productivity is relatively high in the Klaten and Sleman areas and lower in the Magelan area (see Figs. 2.5.1∿2.5.6 and Table 2.5.3).

(3) Degree of Specialization of Agricultural Production

Modernization of agricultural production involves specialization in production of crops best suited to the particular area in view of the given conditions. In this area for example, there is a high degree of specialization in wet paddy, sweet potatoes, and peanuts and a low degree of specialization in maize.

(4) Present Level and Tendency of Yield of Paddy

The future agricultural production is dependent upon whether or not intensification involves reaching the saturation point. In view of the extreme difficulty of expansion of the amount of farmland, the possibility of further intensification of the amount of production per unit of land must be considered. The conclusion for the area under study is that there is still considerable opportunity for intensification of wet paddy production (see Fig. 2.5.7 and Table 2.5.4).

(5) Correlation between Productivity of the Land and Ratio of Level Utilization

For the Sleman and Klaten areas, a low positive correlation has been obtained between the crop yield index and the rate of land use (0.19 and 0.36 respectively). Although the reliability of the data is questionable, this is an indication that there does not seem to be a direct connection between the extent of use of the land and selection of high-productivity crops (except for paddy). Hence, farmers should be given more guidance in the selection of more advantageous field crops.

(6) Strategy for Development of Agricultural Production

The man-land ratio in the area is low. Each family (4.5 persons) only works an average of about 0.2 ha. Nevertheless, the level of production not only of paddy but also of other crops is higher than in other areas. Paddy production is nearly 20% higher in D.I. Yogyakarta than the national average. These facts indicate that the area possess good soil fertility and favorable irrigation conditions.

Rice is the main crop in the area and an indispensable food in terms of the national economy. Improvement of the rate of self-sufficiency in rice is one of the policy priorities in the country's second 5 year development plan. An increase in rice production will bring about an increase in the income of farm families.

Disaster prevention measures will contribute to an increase in agricultural production not only by protecting farmland from flood damage but also by making possible more reliable and efficient use of river sources of irrigation water. In this respect, the best farmland should be protected as a priority.

Table 2.5.3 Crop Yield Index (1971, 1976)

Kabupaten	Kecamatan	1971	1976
Sleman	Sleman	105.95	95.57
	Mlati	106.85	100.46
	Gamping	106.18	102.94
	Godean	111.71	107.48
	Sejegan	104.87	91.51
	Tempel	104.42	102.17
	Turi	101.44	98.15
	Pakem	92.11	92.81
	Tjang Kringan	83.87	99.44
	Ngemplak	93.16	106.44
	Depok	92.94	100.00
	Kalasan	105.85	109.14
	Berbah	110.38	85.28
	Pram banan	99.17	99.49
	Ngaglik	97.65	83.75
Bantul	Bantul	117.5	93.8
Kota Yogyakarta	Umbul harjo	132.7	118.9
	Kota Gede	98.0	107.1
	Mergangsan	136.0	117.8
	Mantrijeron	83.5	104.7
	Gondokusuman	135.8	114.9
	Tegal rejo	80.4	109.9

Table 2.5.3

Kabupaten	Kecamatan	1971	1976
Klaten	Kemalang	83.15	54.83
	Djogonalan	127.08	119.53
	Karang Nongko	124.06	117.95
	Manis renggo	112.47	90.66
	Pram banan	137.08	100.81
	Ganti Warno	125.73	106.56
Magelang	Muntilan	126.18	82.97
	Dukun	79.97	85.26
	Salam	111.10	83.08
	Ngluwar	112.35	74.05
	Srumbung	113.56	87.61

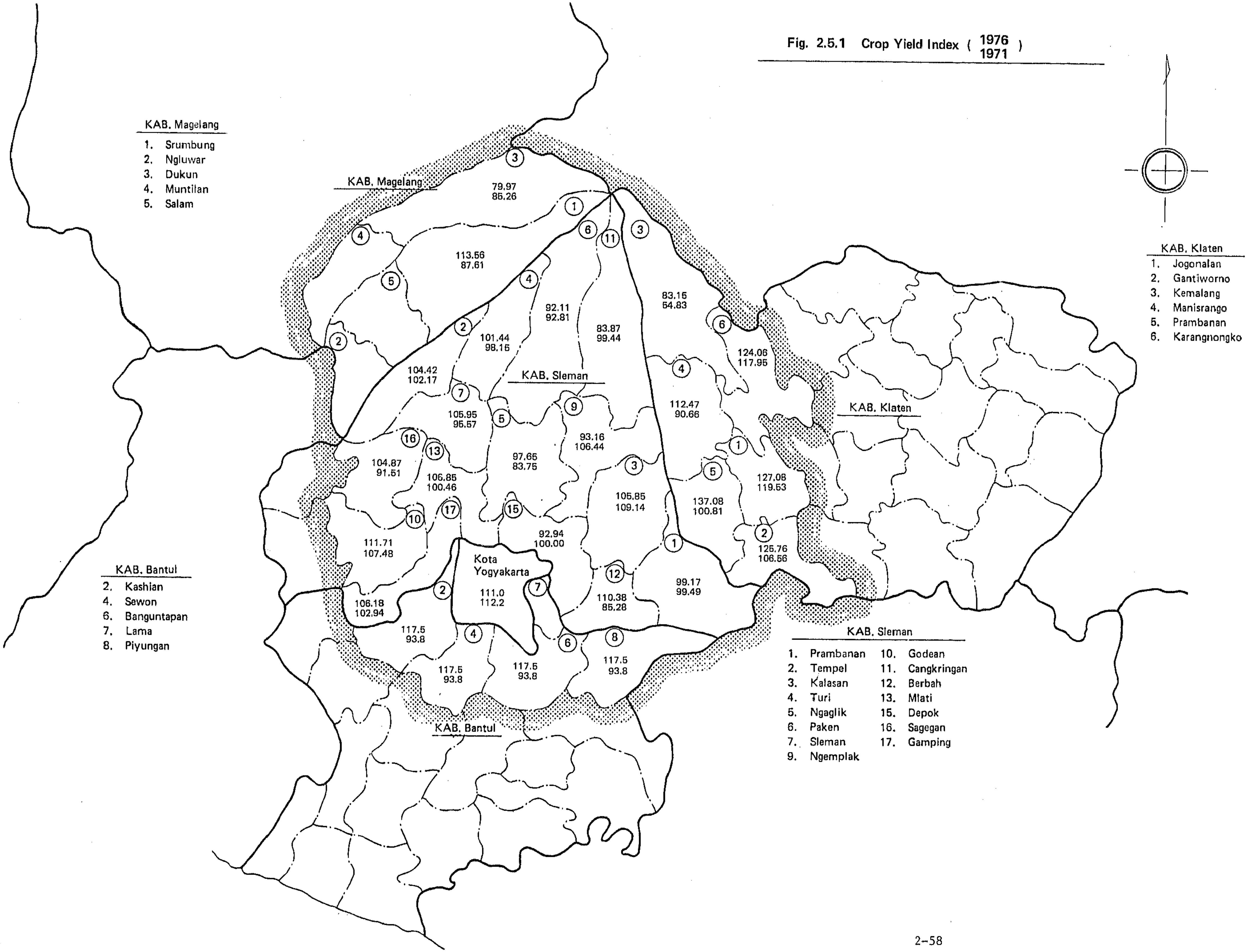


Fig. 2.5.1 Crop Yield Index (1976 / 1971)

Fig. 2.5.2 Crop Yield Index of Kab. SLEMAM
(1971 and 1976)

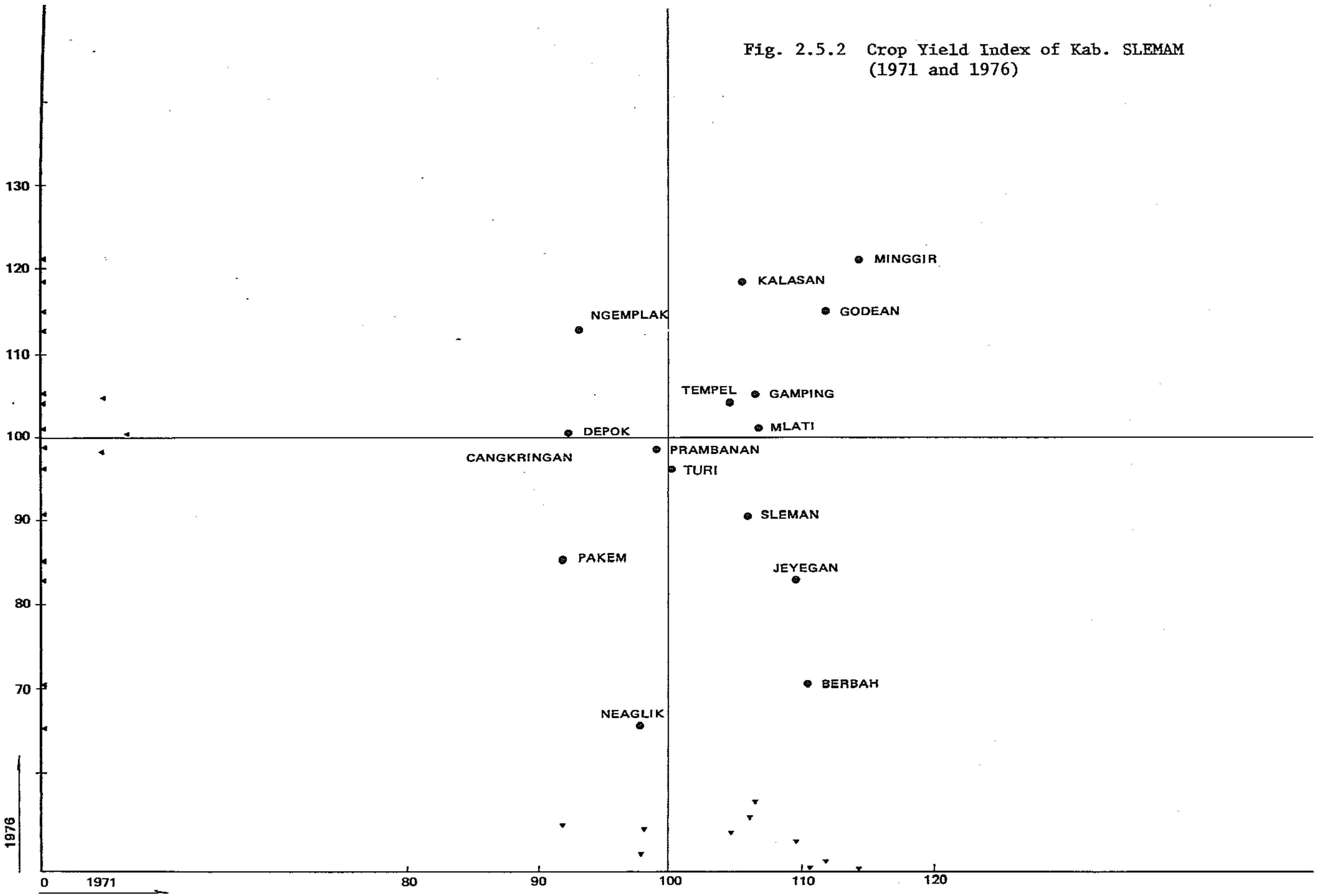


Fig. 2.5.3 Crop Yield Index of Kab. BANTUL (1971 and 1976)

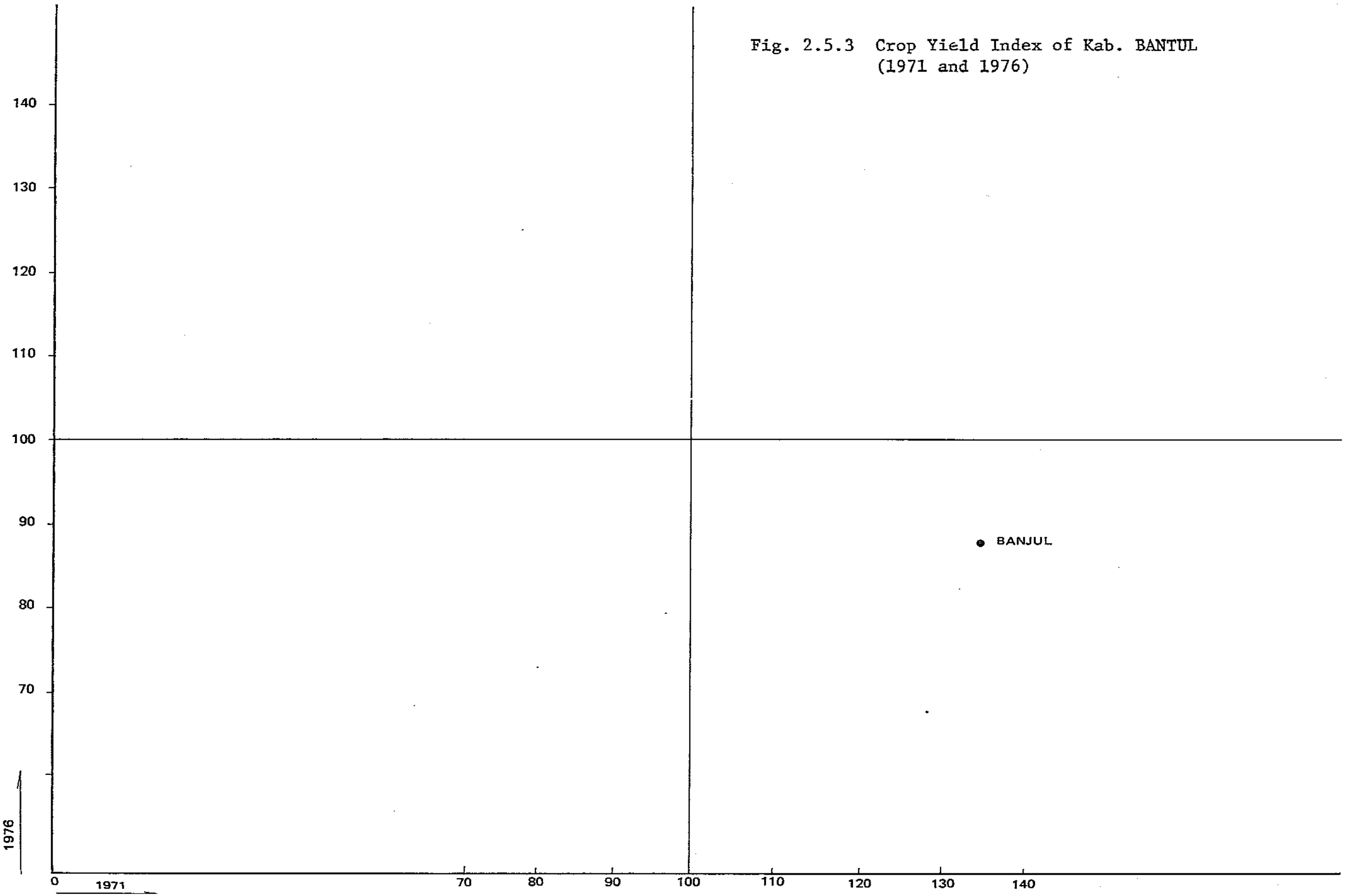


Fig. 2.5.4 Crop Yield Index of Kota YOGYAKARTA
(1971 and 1976)

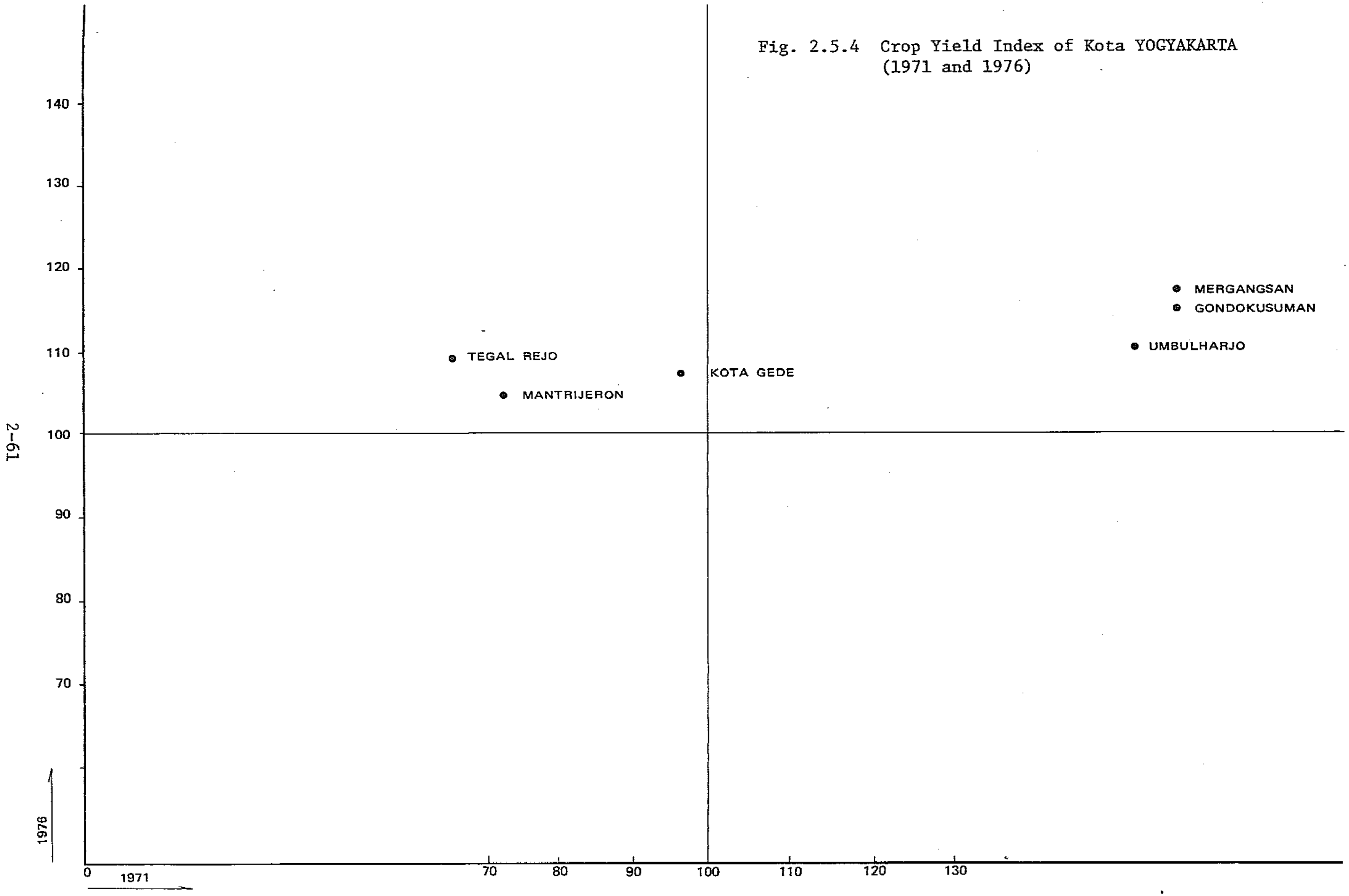


Fig. 2.5.5 Crop Yield Index of Kab. KLATEN
(1971 and 1976)

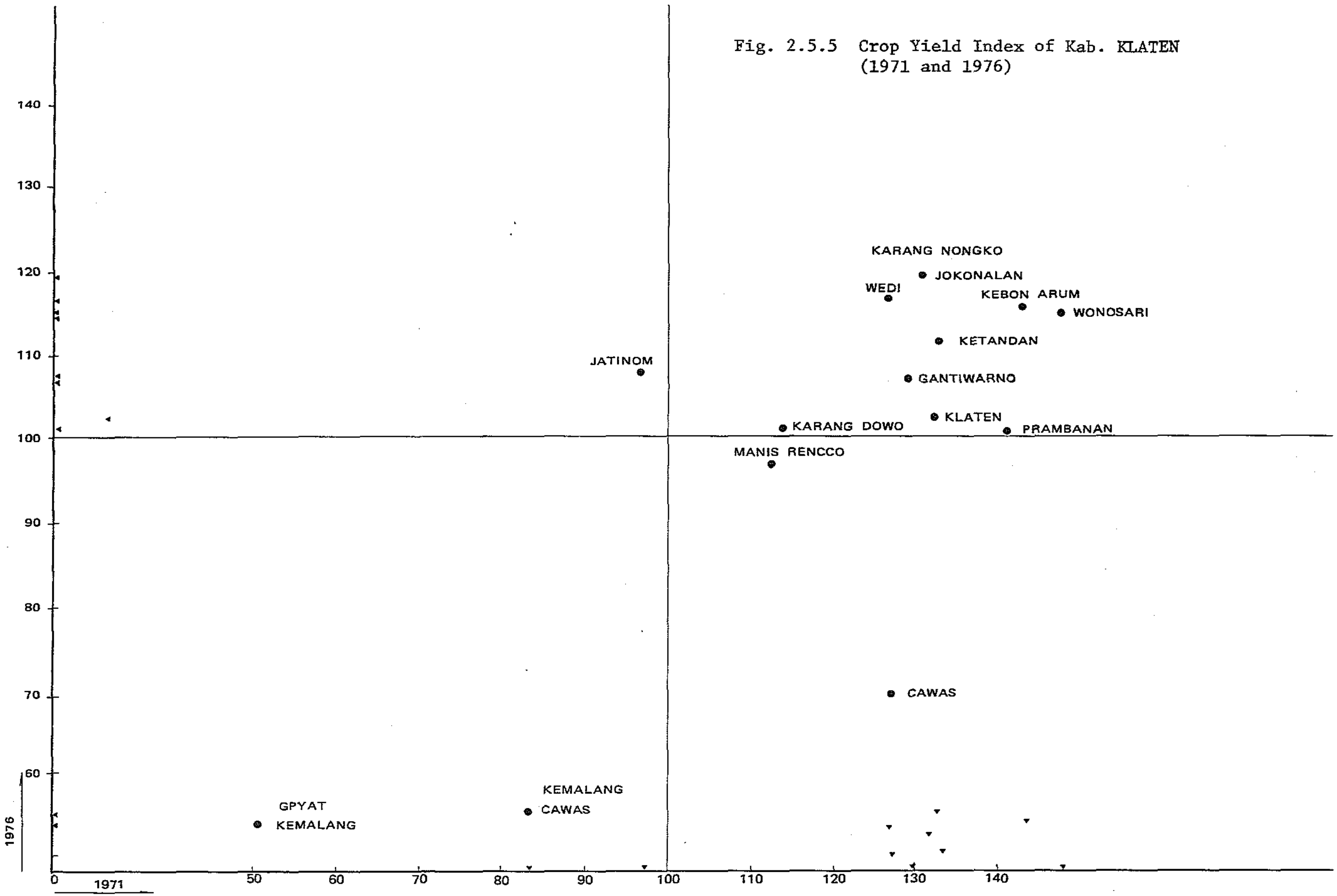


Fig. 2.5.6 Crop Yield Index of Kab. MAGELANG

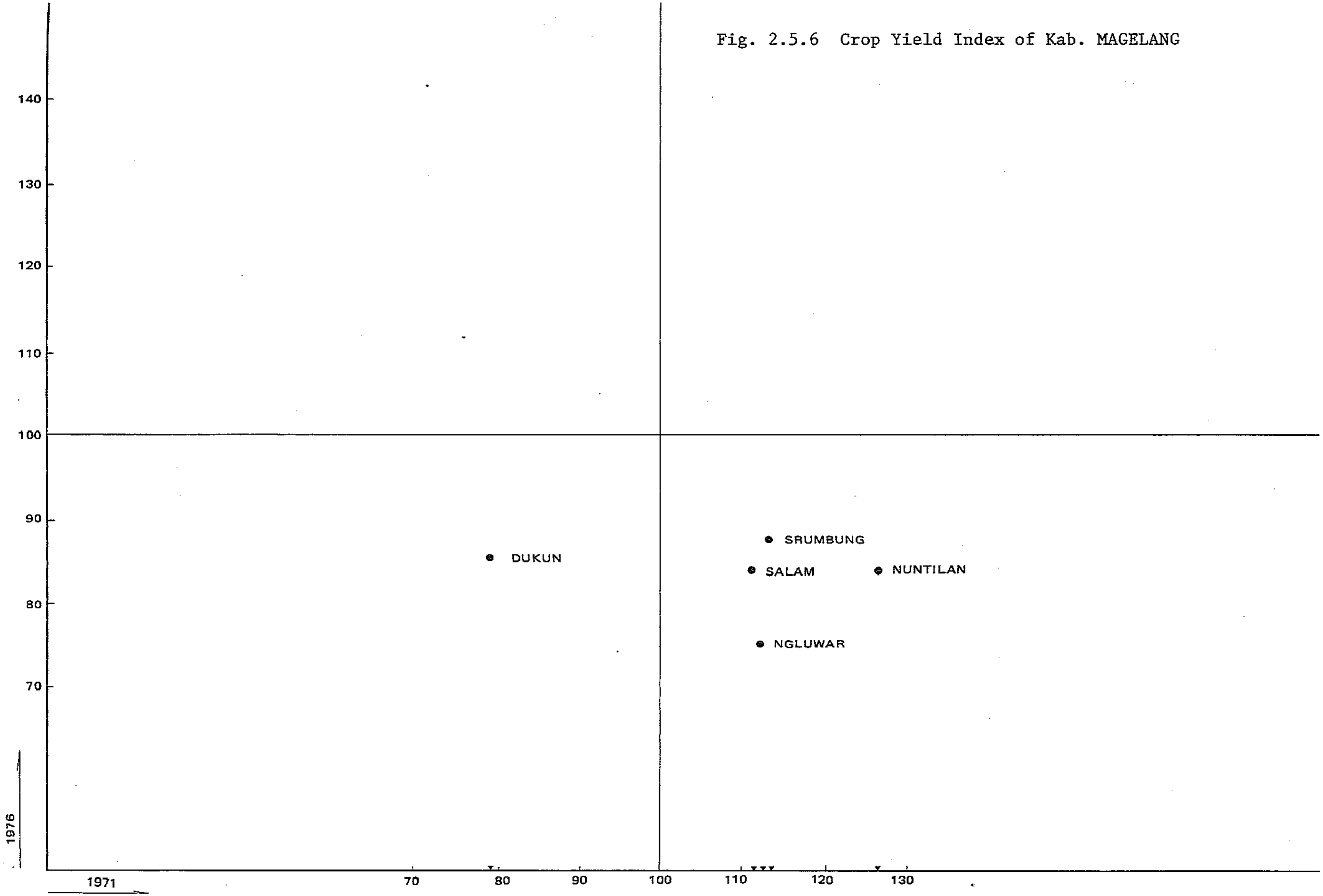


Table 2.5.4 Present Level and Growth Tendency of Paddy

Kabupaten	Kecamatan	a	b	r
Sleman	Sleman	46.49	0.80	0.94
	Mlati	45.63	1.15	0.91
	Gamping	39.28	5.15	0.71
	Godean	46.41	0.70	0.82
	Sejegan	42.55	--0.99	0.67
	Tempel	45.75	1.29	0.75
	Turi	44.15	0.89	0.76
	Pakem	43.16	0.33	0.621
	Tjang Kringan	43.27	0.59	0.796
	Ngemplak	45.70	0.89	0.779
	Depok	47.99	1.11	0.816
	Kalasan	45.77	0.78	0.78
	Berbah	45.53	0.70	00.714
	Prambanan	45.49	0.88	0.926
	Ngaglik	38.12	-3.52	0.713
Bantul	Bantul	46.94	0.32	0.74
	Sewon			
	Kasihan			
	Gondowlung			
	Kota Gede	52.63	0.63	0.70

The possibility of increase in paddy yield is estimated by the following equation;

$\bar{Y} = a + bt + r$

$\bar{Y}$; Paddy yield (q/ha)

a ; Present level of paddy yield (q/ha)

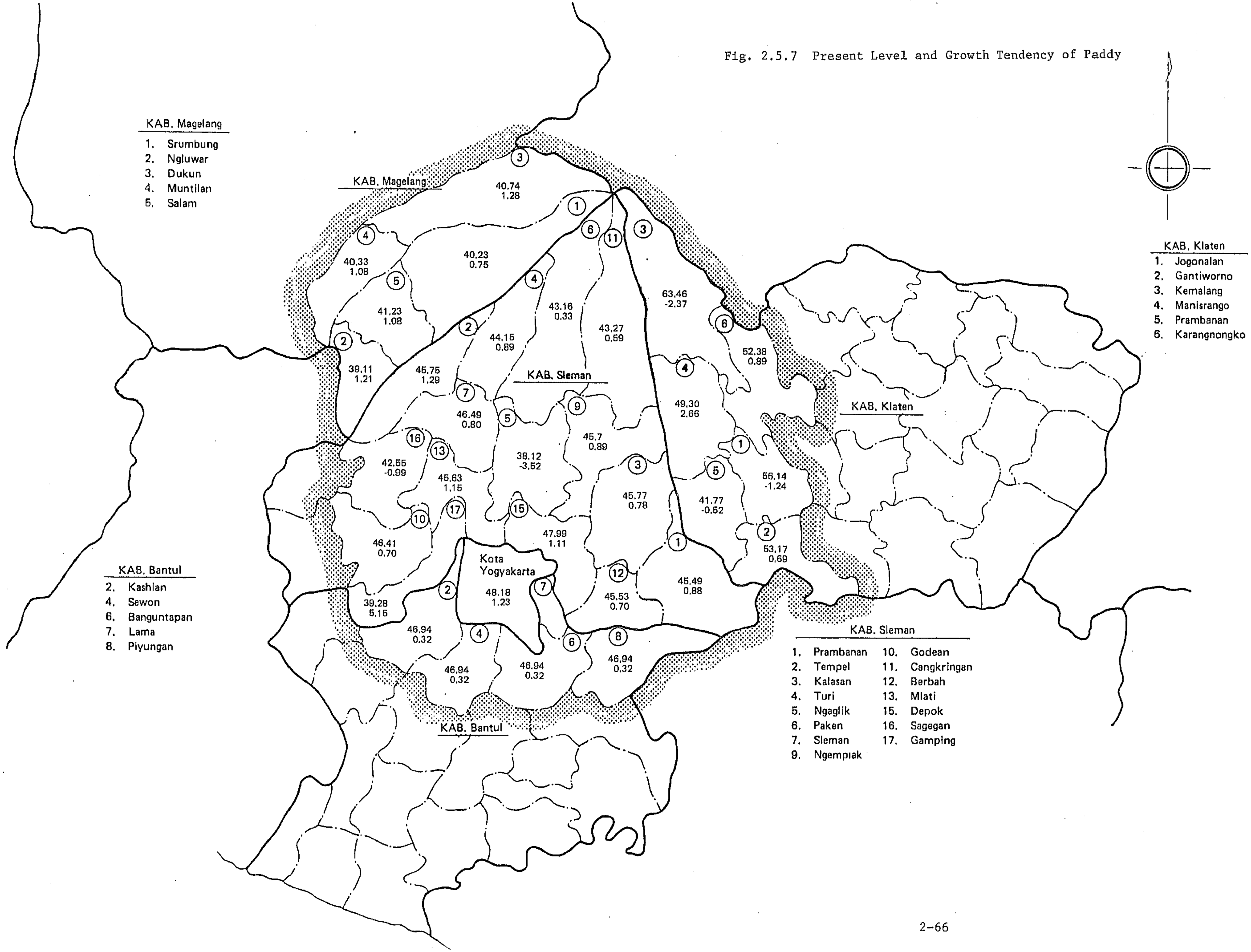
b ; Increasing or decreasing tendency

t ; Period

r ; Error term

Kabupaten	Kecamatan	a	b	r
Klaten	Kemalang	63.46	-2.37	0.52
	Djogonalan	56.14	-1.24	0.91
	Karang nongko	52.38	0.89	0.78
	Manis renggo	49.30	2.66	0.92
	Prambanan	41.77	-0.52	0.39
	Ganti Warno	53.17	0.69	0.55
Magelang	Muntiland			
	Dukun			
	Salam	41.23	1.08	0.93
	Ngluwar	39.11	1.21	0.86
	Srumbung	40.23	0.75	0.36
Kota Yogyakarta	Umbul Harjo	52.85	0.59	0.68
	Kota Gede	52.63	0.63	0.70
	Mergangsan	47.89	0.96	0.93
	Mantrijeron	42.43	2.00	0.95
	Gondokusuman	53.26	0.58	0.61
	Tegal rejo	40.02	2.65	0.86

Fig. 2.5.7 Present Level and Growth Tendency of Paddy



2.5.4 Irrigation

Innumerable irrigation systems exist along the tributaries of K. Progo, K. Opak, and K. Dengeng on the slopes of G. Merapi. Since the main production basis of the area is agriculture (especially paddy), such irrigation facilities are the most important facilities that the area has. Information and data from public works at Magelang, Boyolali, Klaten, and Yogyakarta and the K. Progo Irrigation project is summarized in the following paragraphs concerning the distribution of irrigation facilities in the project area and the distribution of irrigation land and productivity.

(1) Classification of Irrigation Areas

The irrigated land in the area can be classified in the following categories in terms of facility and organizational management:

a) Technical areas:

Areas in which the intake facilities and primary and secondary irrigation channels have been built and are run by the government and tertiary and lower level channels are the responsibility of the villages.

b) Semi-technical areas:

Areas in which intake facilities are built and managed by the national government, and all irrigation channels are the responsibility of the villages.

c) Non-technical areas

Areas in which all intake facilities and irrigation channels are built and run by the villages.

Areas belong to classification are shown in Table 2.5.5.

(2) Irrigation Area Distribution and Scale of Irrigation

The most important irrigation system in the area is the Mataram system, which irrigates an area of 15,000 ha.

On the south side of the main channel are Kab. Bantul and Kota. Yogyakarta which are important areas in term of agricultural production. Considerable irrigation facilities have already been provided. Most of the area is under technical and semi-technical management with only 13% of the land under non-technical management.

On the north side of the main mataram irrigation channel on the slopes of G. Merapi, provision of irrigation facilities is for the most part minimal. The fact that 58% of the land in Kab. Sleman, for instance, is a non-technical area, which is an indication of how badly irrigation facilities are needed in the area. Judging from the tributaries of K. Opak and the results of the social survey, however, the units of irrigation system in the non-technical areas are extremely small for the most part less than 10 ha. It would therefore be better to provide irrigation facilities for the most advantageous farming region instead of for all the farmland.

The main intake facilities are located on rivers with stable courses. In Type-I areas, where lahar and sediment make the river courses unstable, intake facilities are typically only primitive and temporary, except where check dams exist. With the new disaster prevention works forseen in the present plan, river courses can be expected to stabilize, and the number of intake points and amount of irrigation water can be expected to increase.

(3) Irrigation Classification and Productivity

The following is a productivity comparison of the different categories of irrigation areas (technical, semi-technical, and non-technical) in terms of crop yield index numbers and rice productivity.

Productivity is much higher in technical irrigation areas than in other areas. More than 90% of the land in technical irrigation areas falls into either the high or rising category of production in terms of the crop yield index, and only 1% fall into the low production category. Furthermore, rice productivity is about 10% higher than in other areas, and increasing.

Productivity in semi-technical and non-technical areas is rising more slowly since the level of productivity in them is lower than in the technical areas. Since the crop yield index shows that 63∿79%

of the land in such areas fall into either a high or rising production category and 20% into the low production category, there is plenty of room for improvement. The ratio between technical areas and other areas in terms of rice productivity was calculated as 1 : 0.96 ∿ 0.87 for 1976 and 1 : 0.87 ∿ 0.82 for 1981, and shows that the gap is widening.

The slopes of G. Merapi consist mainly of non-technical areas. Therefore, it is necessary to improve irrigation organization there in order to stabilize and increase the productivity. Although a large increase in the supply of irrigation water on the slopes of G. Merapi can only be expected after many years, it will be necessary to stabilize the increase the water supplies from rivers not yet put to use by upgrading temporary weirs to permanent ones and by upgrading non-technical areas into semi-technical or technical areas.

Table 2.5.5 Irrigation Area

	Technical	Semi-technical	Non-Technical	Total
Bantul	3,500ha (18.3%)	13,135ha (68.7%)	2,498ha (13.0%)	19,133ha (100%)
Kota, Yogyakarta	-	700ha (100%)	-	700ha (100%)
Sleman	5,000ha (13.4%)	10,724ha (28.8%)	21,566ha (57.8%)	37,290ha (100%)
Total	8,500ha (14.9%)	24,559ha (43.0%)	24,064ha (42.1%)	57,123ha (100%)

Source: Public Work of Yogyakarta

Table 2.5.5-1 Mataran Irrigation System

	River System	Area (ha)		Design Discharge m^3/sec	Discharge Duty ℓ/s/ha
		Uphill offtake	Below Materan		
Mataran System I	K. Konteng	12	1,319	1.70	1.29
	K. Bedog	47	3,796	2.65	0.70
	K. Winogo	-	1,686	1.35	0.80
	K. Code	-	1,337	1.49	1.11
	Overall	59	8,138	5.00	1.11
Mataran System II	K. Code	149	20	0.06	3.00
	K. Belik	-	300	0.52	1.70
	K. Buntung	90	1,595	2.50	1.55
	K. Tambakbajon	31	1,698	1.27	0.75
	K. Kuning	192	644	1.26	1.95
	K. Opak/Gawe	166	2,569	4.17	1.60
	Overall	628	6,826	3.00	0.45
Overall		687	14,964	5.00	0.32

Source: Kali Progo Basin Study

Table 2.5.6 Irrigation Systems Between
K. Boyong and K. Opak

	Tech. and Semi-Technical		Non-Technical	
	No. of Systems	Area	No. of Systems	Area
K. Boyong		-	18	229.4
		-	83	530.2
K. Belik				
K. Buntung				
K. Tambakbajan	26	1,375.8	191	1,541.5
K. Kuning	10	712.3	59	810.3
	3	156.0	130	668.5
K. Godjahwong	25	1,031.0	108	1,050.0
K. Tepus	4	298.6	78	1,517.4
K. Wareng	2	79.8	19	294.8
K. Bening	1	21.3	12	236.0
K. Pete	5	159.1	6	142.7
K. Opak/Gowe	2	131.3	136	1,712.0

Table 2.5.7 Comparison of Irrigation Areas with Productivity Classification (Unit: No. of Grid mesh)

Productivity Classification		Technical area	Semi-Technical area	Non-Technical
Class-5	High productivity land	271 (33%)	420 (33%)	195 (19%)
Class-4	Land with rising productivity	474 (58%)	373 (30%)	625 (60%)
Class-3	Land with declining productivity	68 (8%)	214 (17%)	16 (1%)
Class-2	Low productivity land	0 (0)	255 (20%)	205 (20%)
Class-1	"	3 (1%)	0	0
Total		816 (100%)	1,262 (100%)	1,041 (100%)
Average Class		4.24	3.76	3.78

Fig. 2.5.8 Comparison of Irrigation Area with Paddy Yield Classification

(Unit: No. of Grid Mesh)

Paddy Yield Class	Technical area 1976	Technical area 1981	Semi-technical 1976	Semi-technical 1981	Non-technical 1976	Non-technical 1981
Class-5 (52.5 g/ha∿)	49	192	69	204	56	86
Class-4 (47.5 g/ha ∿ 52.5)	47	529	152	657	84	200
Class-3 (42.5 g/ha ∿ 47.5)	603	27	651	154	337	702
Class-2 (37.5 g/ha ∿ 42.5)	114	65	383	111	564	49
Class-1 (∿37.5 g/ha)	3	3	7	136	4	4
Total	816		1,262		1,041	
•Average Class of Paddy Yield	3.03	4.03	2.92	3.54	2.65	3.30
•Index of Paddy Yield	100	133	96	117	87	109

Fig. 2.5.8 Irrigation Area Classification

NUMBER

LEVEL	SIGN	NUMBER	
0	x	816	Others
1	*	1041	Non-Technical irrigation area
2	x	1262	Semi-Technical irrigation area
3	x	0	—
4	▮	816	Technical irrigation area
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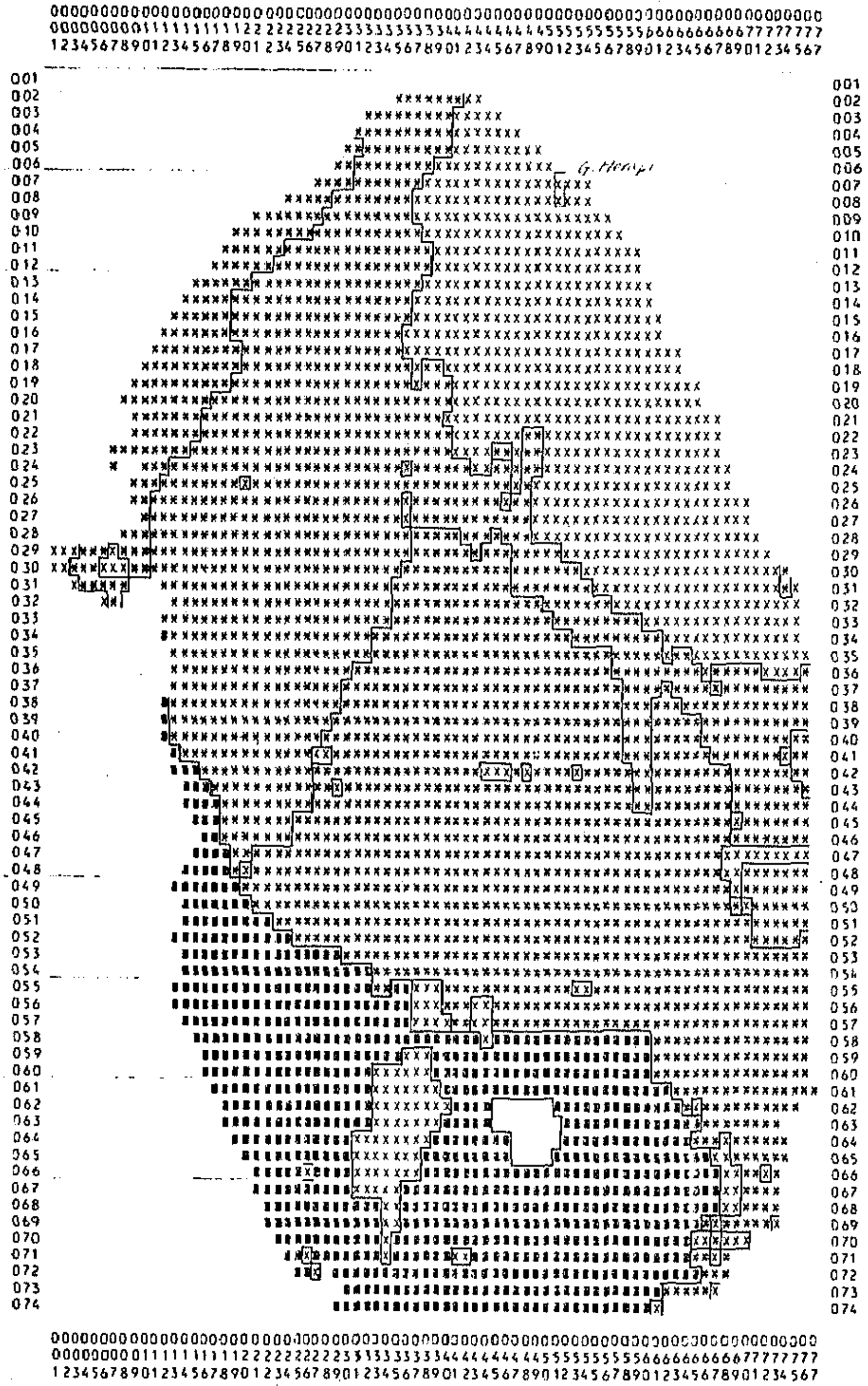


Fig. 2.5.9 Irrigation Area and Crop Yield Classification

NUMBER

LEVEL	SIGN	NUMBER	
0	x	203	Low productivity land
1	x	844	" "
2	x	327	Land with declining productivity
3	x	1574	Land with rising productivity
4	x	987	High productivity land
	ERROR	1763	

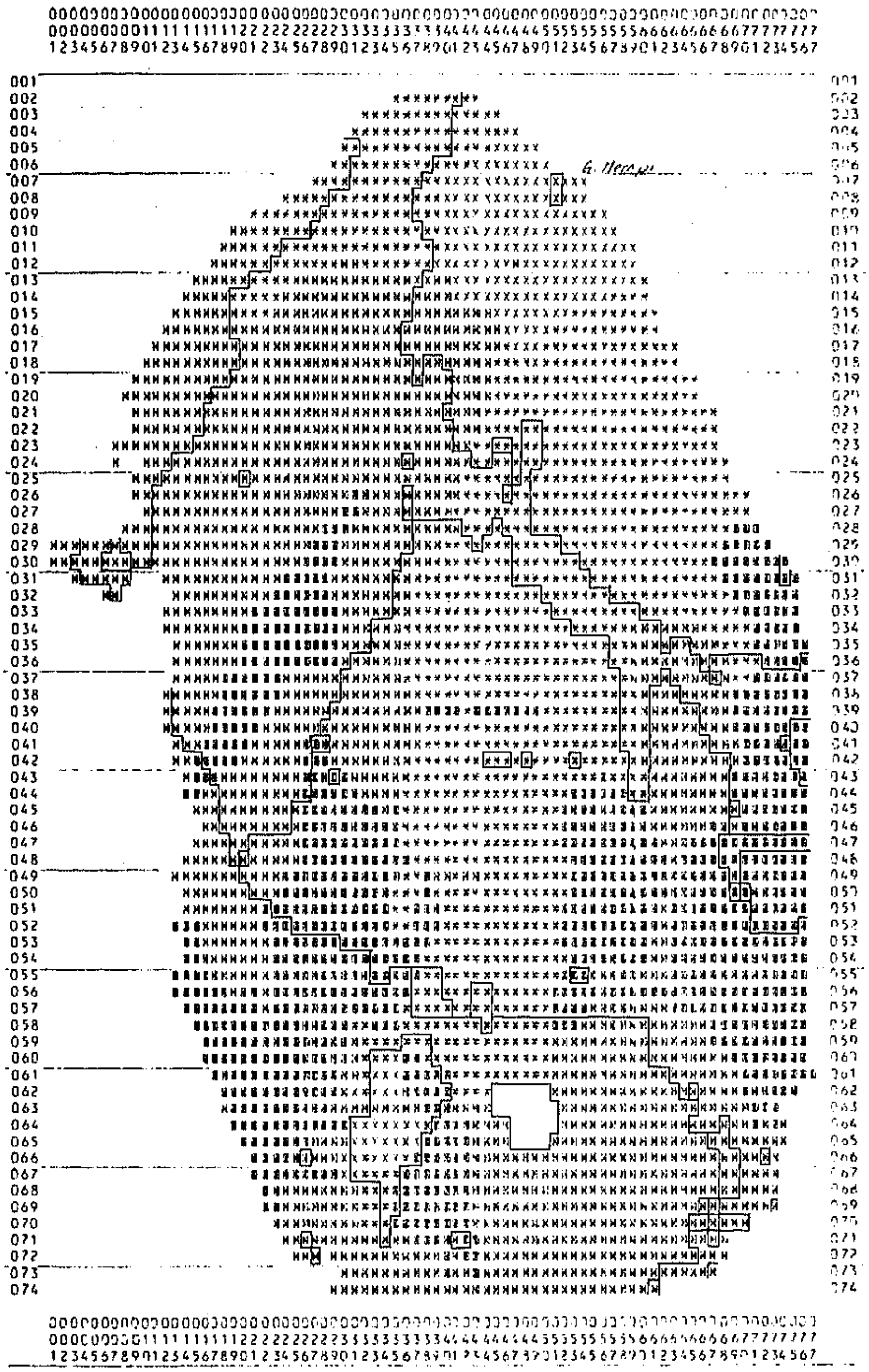


Fig. 2.5.10 Irrigation Area and Yield of Paddy (1976)

NUMBER

LEVEL	SIGN	NUMBER		
0	x	213	~37.5	q/ha
1	*	1127	37.5~42.5	"
2	*	1816	42.5~47.5	"
3	K	373	47.5~52.5	"
4	▮	406	52.5~	"
	ERROR	1763		

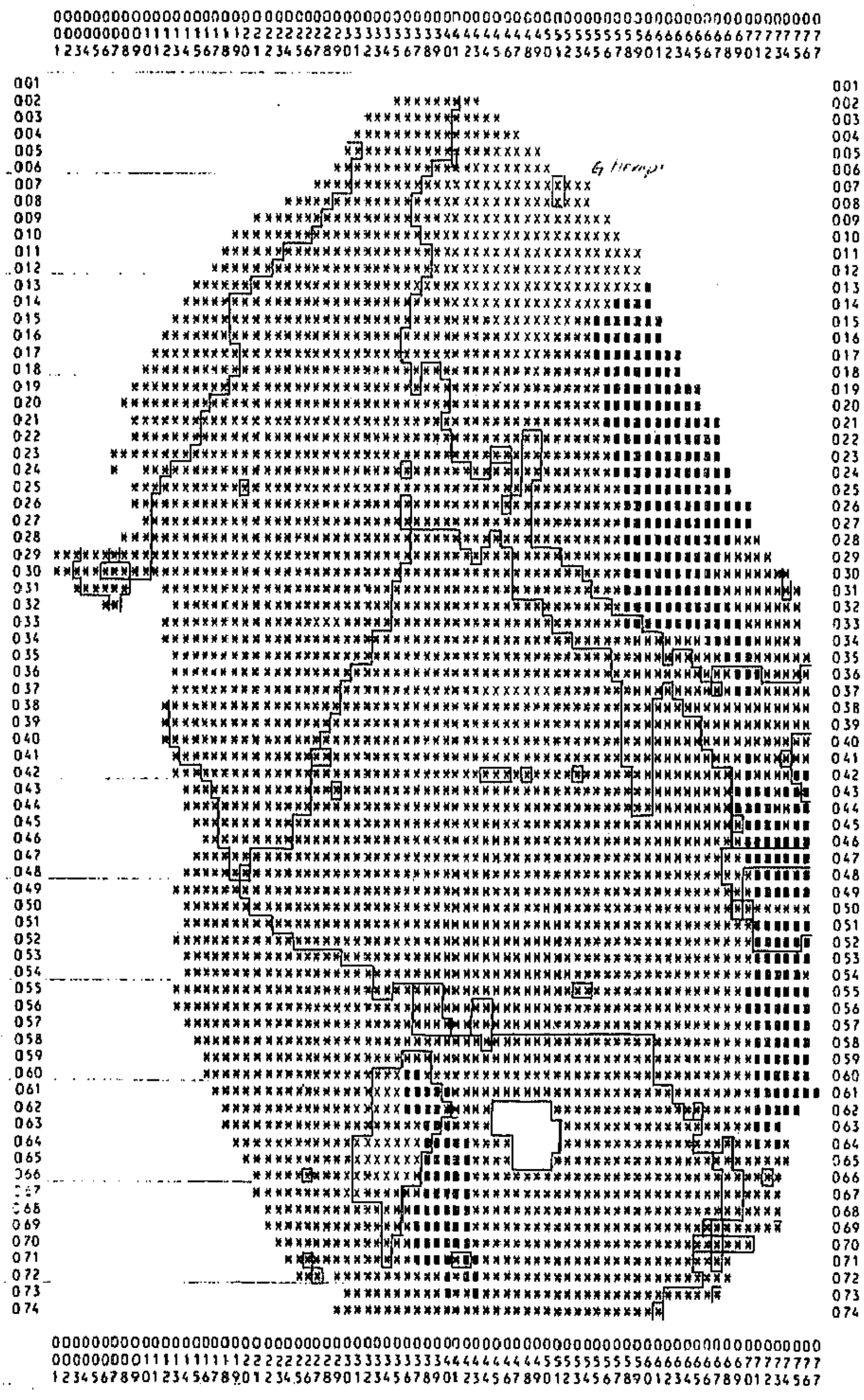
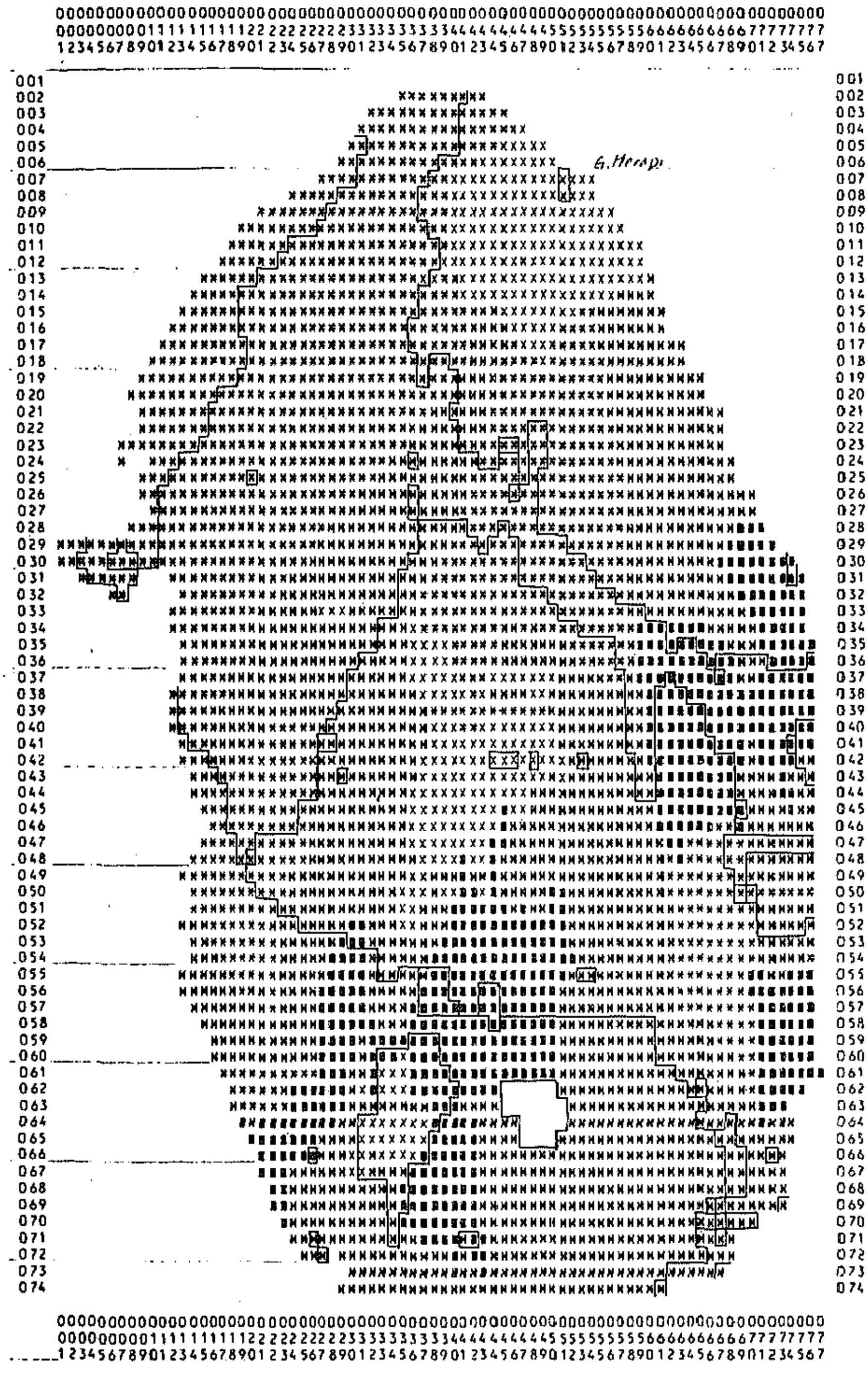


Fig. 2.5.11 Irrigation Area and Tendency of Paddy Yield (1981)

NUMBER

LEVEL	SIGN	NUMBER	
0	x	346	~ 37.5 q/ha
1	ж	245	37.5 ~ 42.5 "
2	ж	1095	42.5 ~ 47.5 "
3	H	1655	47.5 ~ 52.5 "
4	■	594	52.5 ~ "
	ERROR	1763	



2.5.5 Social Infrastructure and Cultural Assets

(1) Road Network

The road hierarchy in Indonesia is as follows:

1) National roads (Jalan negara)
2) Provincial roads (Jalan propinsi)
3) Country roads (Jalan kabupaten)
4) Local roads (Jalan desa)

The project area includes two national roads (one running in a east-west direction from Yogyakarta to Klaten via Prambanan, and the other running in a north-south direction from Yogyakarta to Magelang via Sleman and Tempel) and four provincial roads (one running approx. 25km from Yogyakarta to Kaliurang near G. Merapi via Paken and the other three running from Yogyakarta in the directions of Wonosari, Bantul, and Wates, respectively). In addition, there are three roads extending northward in the direction of G. Merapi from the two national roads, (one from Kalasan to Paken via Ngemplak, another from Yogyakarta to Turi via Ngaglik, and the third from Muntilan to Dukun, including a cross-wise connecting roads from Paken to Tempel via Turi.

Table 2.5.9 gives the results of a traffic volume survey of major roads carried out by the Ministry of Public Work on June 12, 1978.

Fig. 2.5.12 which is based on this table, summarizes the volume of sectional traffic in both directions. This data indicates that the traffic volume for major roads in the area is quite high. High traffic volume is due to the facts that there are no good ports near the area on the Indian Ocean side, and that the main south-circuit railroad passing through the area is not a very functional means of short and medium distance transportation in view of poor maintenance and low frequency of runs. The branch road from Semarang, which has a port and is the provincial capital of Central Java, to Yogyakarta via Magelang, has been abandoned since the railroad bridge over K. Krasak was damaged by Lahar from G. Merapi. Since most of the land transportation in the area is dependent on roads, it is very important to the maintenance and development of the socio-economic activity of the area that its road network be improved and protected from disasters caused by G. Merapi.

In the survey of villages that frequently suffer from G. Merapi disasters, the wish to have the road network, including bridges, improved both for emergency evacuation and access to markets was mentioned often. Since there are few roads running crossways in the G. Merapi area, it is critical that such roads be provided as evacuation routes.

(Note) During the survey there were newspaper reports of implementation of a project for improvement of road networks in the area.

(2) Cultural Assets

Since Yogyakarta is an old center of culture, it has many cultural monuments in its vicinity, the most important being the archeological monument complexes of Prambanan and Borobudur which figure among the most valuable cultural assets of the whole country in terms of attraction of both domestic and foreign tourists. Table 2.5.10 gives admission figures for Borobudur during the past three years.

Although the number of foreign visitors is declining, that of domestic visitors is rising sharply. The total rate of increase for the two complexes taken together was 5.3% in 1975-76 and 16.6% in 1976-77. Most of the visitors to Borobudur also visit Prambanan in view of its convenient assessibility.

In view of the importance of these archeological complexes to the economy of the area in terms of tourism revenue, studies are in progress for the purpose of promoting the tourism development of the area.

(3) Other Social Infrastructure

Other social facilities indispensable to the life of the area include educational facilities, hospitals, health centers, other medical and health facilities, sports and recreational facilities, mosques, other religious facilities, public meeting places, halls, and offices.

In the survey the people in G. Merapi disaster areas expressed the desire to have school buildings that can serve the additional purpose of housing refugees in times of disaster. Table 2.5.11, gives figures on the number of schools in the area at present, including elementary, intermediate, and high school, universities and colleges, and specialized schools. The number of schools is by far the least in the nuée ardente hazard area, which is also extremely deficient in other social facilities.

Table 2.5.12 gives figures on the number of hospitals in the area. There is not a single hospital in nuée ardente hazard area. The average number of hospitals for all danger zones is only one for every 19,000 inhabitants and every $12km^2$.

Table 2.5.9 Daily Traffic Volume (Jan. 12, '78)

Post	Direction	Sedan	Minibus	Bus	Truck	Motor Cycle	Bicycle	Cart	
C 001	To Yogyakarta	2,487	173	300	298	2,568	2,683	6	National road
	To Sleman	2,468	136	290	350	2,526	2,555	11	
	Total	4,955	309	590	648	5,094	5,238	17	
C 002	To Yogyakarta	3,864	997	268	1,176	4,230	5,888	42	"
	To Klaten	4,219	1,180	409	1,605	4,586	4,746	29	
	Total	8,083	2,177	677	2,781	8,816	10,634	71	
C 202	To Yogyakarta	1,213	114	104	779	1,364	2,105	7	Provincial road
	To Wates	1,424	186	114	540	1,249	2,314	0	
	Total	2,637	300	218	1,319	2,613	4,419	7	
C 203	To Yogyakarta	330	563	49	86	2,699	17,189	107	"
	To Bantul	612	1,253	226	161	3,451	16,166	208	
	Total	942	1,816	275	247	6,150	33,355	315	
C 204	To Yogyakarta	683	146	30	140	535	204	0	"
	To Wonosari	739	188	42	213	566	298	2	
	Total	1,422	334	72	353	1,101	502	2	
C 205	To Yogyakarta	1,591	45	36	85	1,728	1,398	49	"
	To Kaliurang	591	32	24	45	1,331	1,404	12	
	Total	2,282	77	60	130	3,059	2,802	61	

Fig. 2.15.12 Sectional Traffic Volume

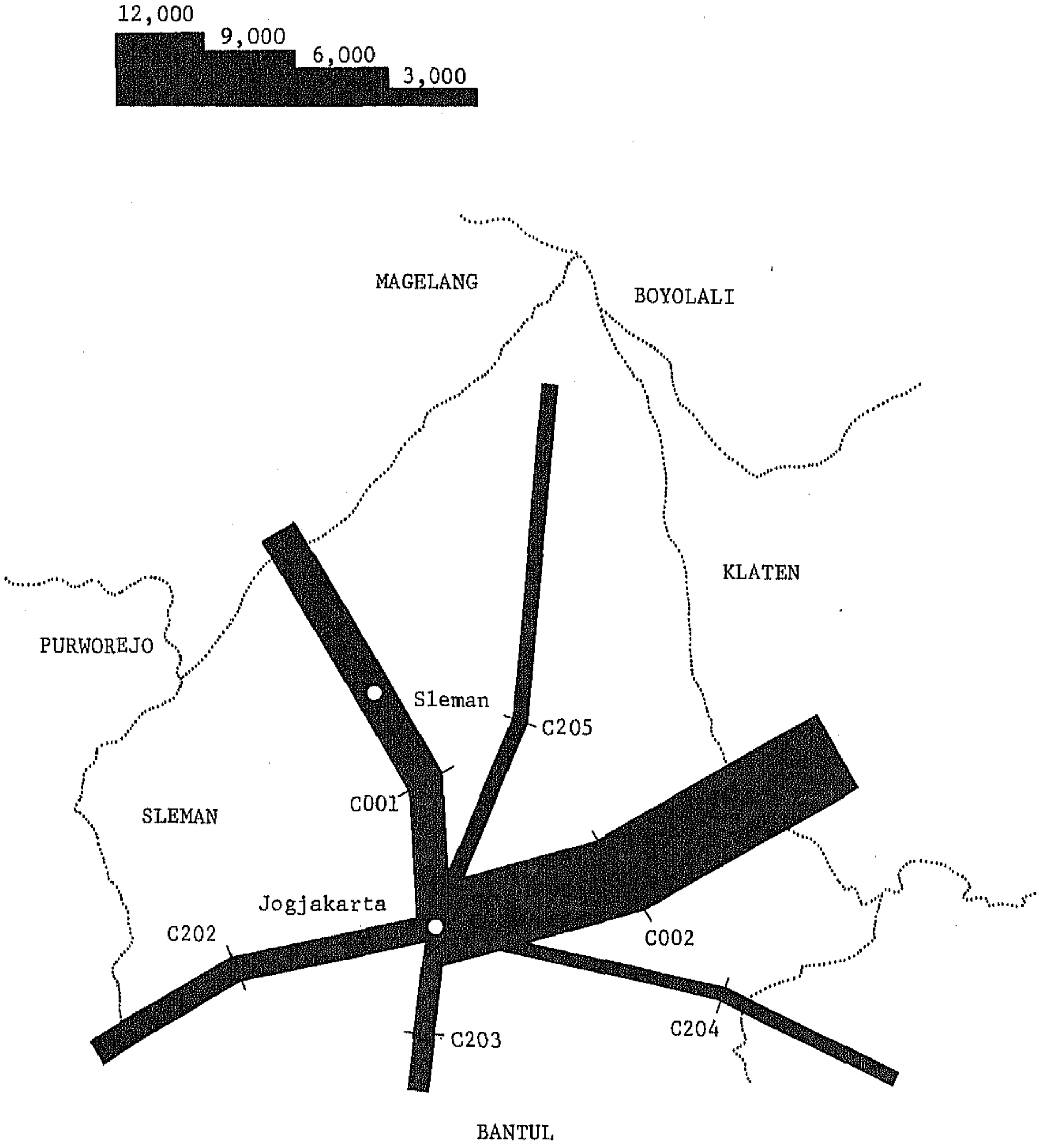


Table 2.5.10 Number of Visitors to Borobudur

Year	Domestic	Foreign	Total
1975	350,285	49,074	399,359
1976	373,293	46,025	419,318
1977	443,880	45,122	489,002
1978 (Up to June)	187,691	20,069	207,760

Table 2.5.11 Number of Schools

Type	No. of Schools	No. of Schools per Kelurahan	No. of Persons per School	No. of Schools per Km^2
Nuee Arlente	36	1.4	2,175	0.26
Type I	92	3.4	1,171	1.18
Type II	135	2.8	1,444	0.92
Type III	56	7.0	1,016	0.79
Type IV	561	5.7	1,608	1.36
Total	880	-	-	[illegible]
Average	-	4.2	1,523	1.04

Table 2.5.12 Number of Hospitals

Type	No. of Hospitals	No. of Persons per Hospital	Km^2 per Hospital
Nuee Ardente	0	-	-
Type I	4	26,922	19.5
Type II	11	17,725	13.4
Type III	1	56,900	71.0
Type IV	55	16,400	7.5
Total	71	-	-
Average	-	18,871	11.9

2.6 History of Damage and Warning

2.6.1 Damage between 1969-1976

(1) Damage of Paddy Field (Table 2.6.1)

The area of paddy field damaged between 1969 and 1976 is summarized as follows: (unit = ha)

Year	K. Krasak	K. Bebeng	K. Putih	K. Gendol
1969	20.8	41.5	94.4	156.0
1970	-	-	-	-
1971	-	-	-	-
1972	-	-	-	-
1973	-	-	-	42.5
1974	-	90.9	-	-
1975	108.0	18.4	34.4	-
1976	280.0	90.9	-	-
Total	408.8	192.3	154.7	198.5

(2) Flooding and Sedimentation Area

The flooding area and sedimentation area of recent floods were surveyed with questionnaires along K. Krasak and K. Putih. The results are summarized as follows:

River	Year	Damage Area			Number of collapsed houses
		Flooding Area (ha)	Sedimentation Area-ha	(depth-m)	
K. Putih	1976	13.2	3.4	(0.8)	1
"	1975	13.5	9.0	(0.8)	2
K. Krasak	1976	59.6	22.7	(0.4)	5
"	"	0.3	0.3	(0.7)	2
"	"	250.1	150.0	(0.8)	67
"	1975	18.4	4.6	(0.6)	40

2.6.2 Warning System

Considering the nature of the disasters in this area, there is a limit to what the provision of facilities can accomplish in the way of preventing and mitigating damage from volcanic eruptions and from the volcanic matter emitted by such eruptions. Accordingly, it is necessary to arrange for a better warning system in addition to facility planning and improvement of land use.

Damage is primarily caused by nuée ardente resulting from the volcanic eruptions and lahar and banjir resulting from the volcanic matter emitted and subsequent rainfall. Since danger zones have already been outlined with respect to nuée ardente on the basis of long years of observation of volcanic activity and volcanic research, it is already possible under present conditions to issue evacuation orders in advance of disasters. In this study we will confine ourselves to consideration of an warning system for lahar and banjir. The next section outlines existing the warning service prediction, evacuation and rescue services.

(1) Existing Warning Service

Existing observation posts and communication systems are shown in Table 2.6.2 and Fig. 2.6.1.

(2) Relationship between Occurrence of Lahar and Rainfall

What is important in warning system for prevention of lahar-caused disasters is the timing of warning and commencement of evacuation. In order to effectively prevent disasters through warning, at least one or two hours prior notice is necessary for communication and the evacuation operation itself. Since the river basin areas in question are very small (generally less than $30km^2$ in area) the only forecasting method that can be adopted is that based on the amount and the pattern of rainfall. Since lahar usually occurs at rainfall peaks or immediately thereafter and since the lahar flow will reach a village within a 30 mins, to an hour, prediction will have to be made and warnings will have to be issued an hour or two before the lahar actually occurs. Accurate prediction is no easy matter.

In this area the rainfall peak usually occurs between 4:00 and 5:00 P.M. Since 70-80% of the day's rainfall occurs in the three to four hour period before and after the peak, it is possible to a certain extent to recognize danger in advance. Nevertheless, warning are not yet very reliable because of the paucity of relevant data.

Table 2.6.3 and give information on the rainfall prior to and during the occurrence of lahar in nine instance during the period 1973-76.

(3) Correlation of the Rainfall of Observation Stations

Since rainfall in this area tends to concentrate over a very small area during a short period of time, it will be necessary to have standard observation stations in each area for an effective warning system.

The main observation stations in the area at the present time a are located at Babadan, Plawagan, and Ngepos. A coefficient γ to correlate rainfall between the stations has been sought on the assumption that there is a straight line relationship with respect to the monthly and daily amounts of rainfall in the rainy season in 1976. The results shown below indicate that there is considerable correlation between Plawagan and Ngegos, but very little between Babadan and either of the other two stations. Plawagan and Ngepos are therefore more appropriate as standard observation stations.

Observation stations	Correlation between two stations	
	Monthly rainfall	Daily rainfall (> 50mm/day)
Babadan and Plawagan	-0.08	0.304
Babadan and Ngepos	0.06	0.337
Plawagan and Ngepos	0.84	0.717

(4) Evacuation and Rescue Systems

Under present conditions one can not expect a very high precision warning service since the rainfall areas are very small (30-59km^2) and there has not yet been long-term observation of lahar disasters and water and hydrological conditions. Nevertheless it is very important that a suitable evacuation and rescue system be established in order to prevent damage and casulaties and lessen the anxiety of residents since this is a very densely populated area (1,584 person/km^2).

Table 2.6.2 Observation Posts and Equipment

		Complete	Telescope	Radio-Telephone	Telephone	Rainfall
1	Babadan	o	o	o	o	o
2	Plawagan	o	o	o	o	o
3	Ngepos	-	-	o	o	-
4	Deles	-	-	-	-	o
5	Kringin	-	-	-	o	o
6	Selo	-	o	-	o	o
7	Jka Kar	-	o	-	o	o

Table 2.6.1 List of Lahar Flood Damage - Paddy Field (1)

(unit = ha)

River / Date	K. Progo System						K. Opak System			K.Denkang	
	K.Krasak	K.Bebeng	K.Putih	K.Blonkeng	K.Batang	K.Snow	K.Gendol	K.Kuning	K.Boyong	K.Woro	
	Type-1	Type-1	Type-1	Type-1	Type-III	Type-III	Type-II	Type-III	Type-III	Type-II	
25, Nov. '76	282.0	16.5									298.5
5, Mor. '75	46.0	15.4	33.5								94.9
12, Mor.		3.0	0.9								3.9
1, Oct.											
3, Oct.	62.0										62.0
1, Oct. '74		72.0									72.0
Nov.		18.9									18.9
23, Sep. '73							38.5				38.5
3, Oct.							0.3				0.3
10, Nov.							0.5				0.5
12, Nov.							0.7				0.7
16, Nov.							2.5				2.5
1, Jan. '70											

list of Lahar Flood Damage - Paddy Field (2)

(unit = ha)

River / Date	K. Progo System .						K. Opak System			K.Denkang	
	K.Krasak	K.Bebeng	K.Putih	K.Blonkeng	K.Batang	K.Snow	K.Gendol	K.Kuning	K.Boyong	K.Woro	
	Type-1	Type-1	Type-1	Type-1	Type-III	Type-III	Type-II	Type-III	Type-III	Type-II	
6, Jan. '69	20.8										176.8
8, Jan.		25.0									25.0
20, Jan.											
22, Jan.											
24, Jan.											
3, Feb.											
10, Feb.											
26, Feb.											
15, Mar.			28.2								28.2
21, Mar.			0.5								0.5
24, Mar.			11.0								11.0
26, Mar.											
29, Mar.			77.0								97.0
5, Apl.		41.5	5.0								46.5
20, Apl.			0.9								0.9
21, Apl											

Fig. 2.6.1 Warning System

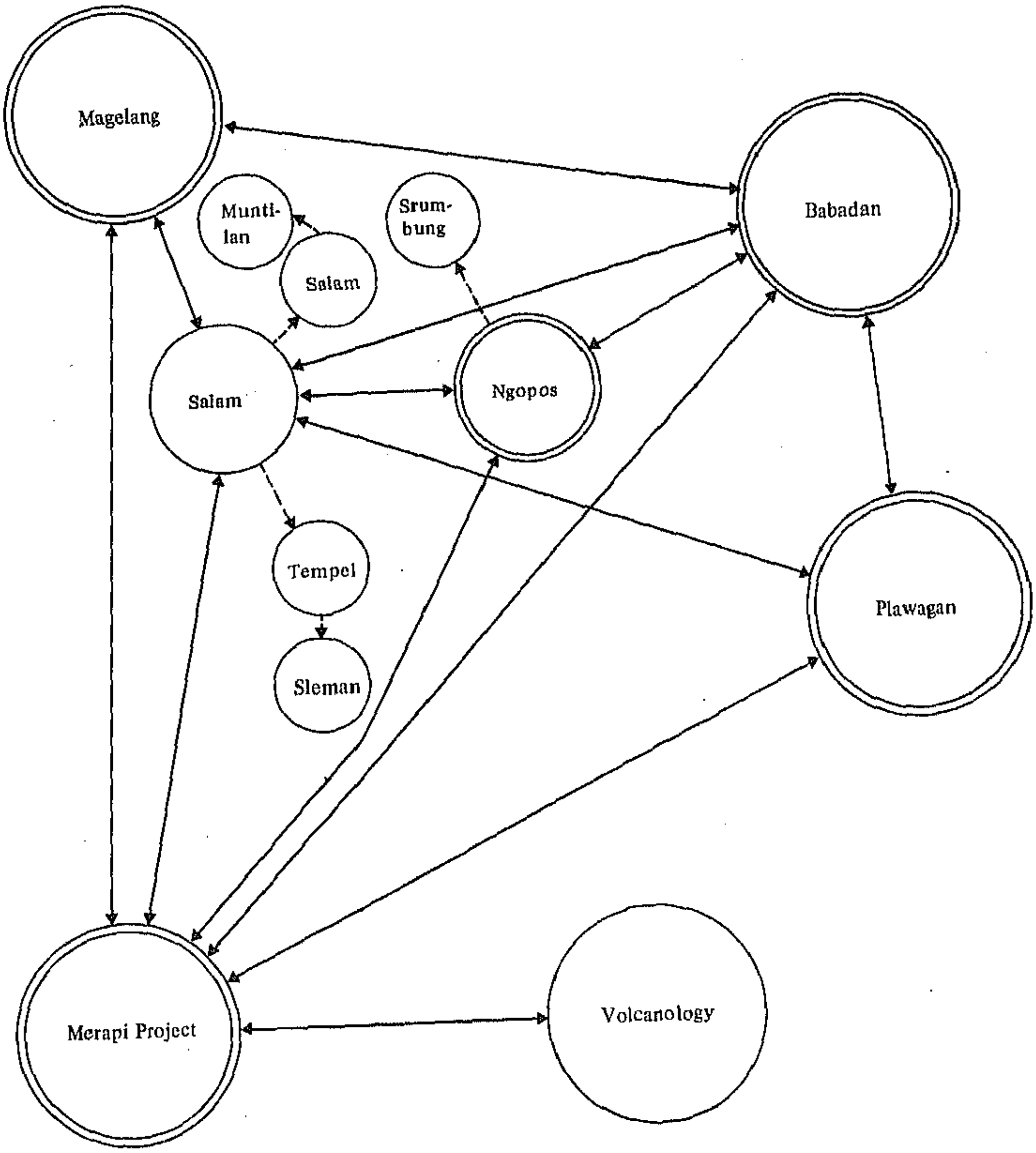


Table 2.6.3 Duration of Rainfall and Rainfall Pattern at Lahar

Year	Month	Day	Duration of rainfall	Daily rainfall	CR*	ER*	t*	ER/t*	CR-1*	CR-2*	t_o*
1973	Sept.	23	98.8	20.8	98.4	20.0	1.0	20.0	18.4	78.4	9.00
"	Nov.	10	94.9	76.1	75.9	54.8	4.0	13.7	46.9	35.9	17.00
"	"	12	109.0	26.0	101.4	17.0	2.0	8.5	86.4	84.4	15.00
1974	Nov.	22	96.6	30.9	87.7	22.0	2.0	11.0	77.7	65.7	16.00
1975	Mar.	5	232.0	200.0	230.0	198.0	3.0	66.0	150.0	121.0	16.00
"	Oct.	1	75.0	75.0	75.0	75.0	6.0	12.5	60.0	55.0	20.00
"	"	3	90.3	72.0	70.7	53.0	2.0	26.5	21.7	17.7	16.00
1976	Nov.	17	172.5	166.9	146.7	129.8	3.0	43.2	79.2	21.7	16.00
"	"	25	281.2	241.6	233.6	193.6	3.0	64.5	158.4	102.0	16.00

* Notes:

CR - cumulative rainfall amount
ER - effective rainfall amount
t - effective time preceeding Lahar
ER/t - rainfall intensity
CR-1 - cumulative rainfall 1-hour prior to Lahar
CR-2 - " " 2-hours "
t_o - estimated time of Lahar occurance

2.7 Disaster Areas

2.7.1 Disaster Classification

The following types of disasters occur in the area;

(1) Slopes of G. Merapi;

- Disasters caused directly by volcanic eruptions - nuée ardente { Avalanche type / Explosion type

- Disasters caused by secondary movement of volcanic material ------------------ { Lahar / Banjir

(2) K. Progo and K. Opak

- Disasters caused by sediment deposits in river courses.

2.7.2 Area Classification in terms of Nuée Ardente, Lahar and Banjir

The forms of movement of sediment, which very according to the forces and materials, can be classified as follows:

Form of Movement of Sediment

Category	Form of movement of sediment
Nuée Ardente	Falling Callapse
Lahar	Massive movement { a) Mud flow b) Tractive like Massive movement
Banjir	Individual transport { a) Bed load b) Suspended load

The form that disasters take and the way of calculating the amount of sediment discharge vary according to the form of sediment movement. The form at a single location also varies, however, according to the amount of discharge, water depth, particle diameter, etc.

The classification of forms of sediment movement correspond to the same three categories nuée ardente, lahar, and banjir which have been used to divide the hazard areas in terms of the distance the nuée ardente and lahar reaches. Such area classification is based on existing information, surveys, and geomophological analysis. Fig. 2.7.1 and 2.7.1' indicates the areas of activity of nuée ardente, lahar, and banjir in 1930, 1961, and 1969. The geomorphological analysis and related studies listed below are summarized in Fig. 2.7.2 and Fig. 2.7.3;

(a) Analysis of relationship of elevation and distance from the mountain top (or the divide).

(b) Analysis of relationship between river bed gradient and length of flow course.

(c) Analysis of the features of large gravel deposits.

(d) Study of river piracy points.

(e) Study of expected change in logitudinal profile of river-bed.

(f) Theoretical study of mud flow.

(1) Nuée Ardente Zone

a) Study on Basis of Existing data and Surveys

The available data for 1930 and 1969 indicates that nuée ardente has been limited to Type-I areas, reaching approximately 700m above sea level (about 9km from the crater).

Judging from the land use patterns and geological survey results, nuée ardente probably once reached the vicinity 500m above sea level in areas to the east (Type-II and Type-III) when there was large-scale volcanic activity in the past.

b) Topographical Analysis, Etc.

Using current data, the areas of movement in which gravity is dominant (nuée ardente areas) are as follows:

(1) West part (Type-I) At elevation of 900m and above.

(2) East part (Type-II and -III) At elevations of 700m and above

With inference of past activity, the elevation figures are as follows:

(1) West part 900m and above

(2) East part 800m and above

Considering that longitudinal profile of the non-continuity points of river profiles and river piracy points (in upper slope areas) are located between 1,000m and 1,400, of elevation, the areas where topographical formation by nuée ardente is dominant are probably above 900m in the west part of the project area and above 700m in the east part.

c) Outlining of Nuée Ardente Zone

The nuée ardente zone has been outlined as follows on the basis of the above considerations:

In the west part of the area it is probable that the nuée ardente only reaches the vicinity of the 700m elevation level, but about 1km of horizontal distance was added to be on the safe side. The nuée ardente hazard zone has been extended to the 650m level (about 10km from the crater) in the vicinity of K. Krasak. In the case of K. Pabelan, it extends to about 700m above sea level.

Although the scale of volcanic activity has declined somewhat in recent years in the east part of the area, it is still considered justifiable to have that hazard zone extend to about 600m above sea level in view of the distance to which nuée ardente reached in the west area (Type-I area). At K. Woro it extends to about the 550m elevation level.

(2) Lahar zone

a) Study on the Basis of Existing Data and Surveys

In recent history Lahar flows have clearly halted at the following elevations:

1930	Lahar	K. Batang	570m above sea
"	"	K. Blongkeng	530m "
1961	"	K. Batang	660m "
1969	"	K. Bebeng	500m "
"	"	K. Putih	650m "

The lowest elevation is that of 500m for K. Bebeng, where the river bed gradient is about 3 deg. However, considering the past instances and the large content of volcanic ash and other fine particles, a high-concentration flow can be expected to reach even further downstream.

b) Topographical Analysis, Etc.

Since points where there is a sharp change in the rate of change of the river bed gradient are the same points where the form of sediment movement changes, the following table indicating the elevation of the boundaries between lahar and banjir has been constructed. The highest boundary elevation is 570m, in the case of K. Pabelan, and the lowest is 370m, in the cases of K. Woro and K. Gendol. As for the river gradients at these points, the largest is 5% (2.90 deg.) for K. Boyong, and the smallest is 2.6% (1.5 deg.) for K. Blongkeng; 2 deg. is the rough average. Furthermore, the results of the survey on features of large gravel deposited in K. Krasak indicate a change in deposit features at about the 500m elevation level. (See Table 2.7.1)

c) Outlining of Lahar Zone

The lahar zone has been outlined as follows on the basis of the above considerations:

K. Pabelan	570m	K. Boyong	420m
K. Blonkeng	420m	K. Kuning	410m
K. Putih	420m	K. Gendol	370m
K. Batang	420m	K. Woro	360m
K. Krasak	420m		

(3) Banjir Zone

The zone downstream from the lahar zone has been designated as the banjir zone.

See Fig. 2.7.4 for the above area classifications.

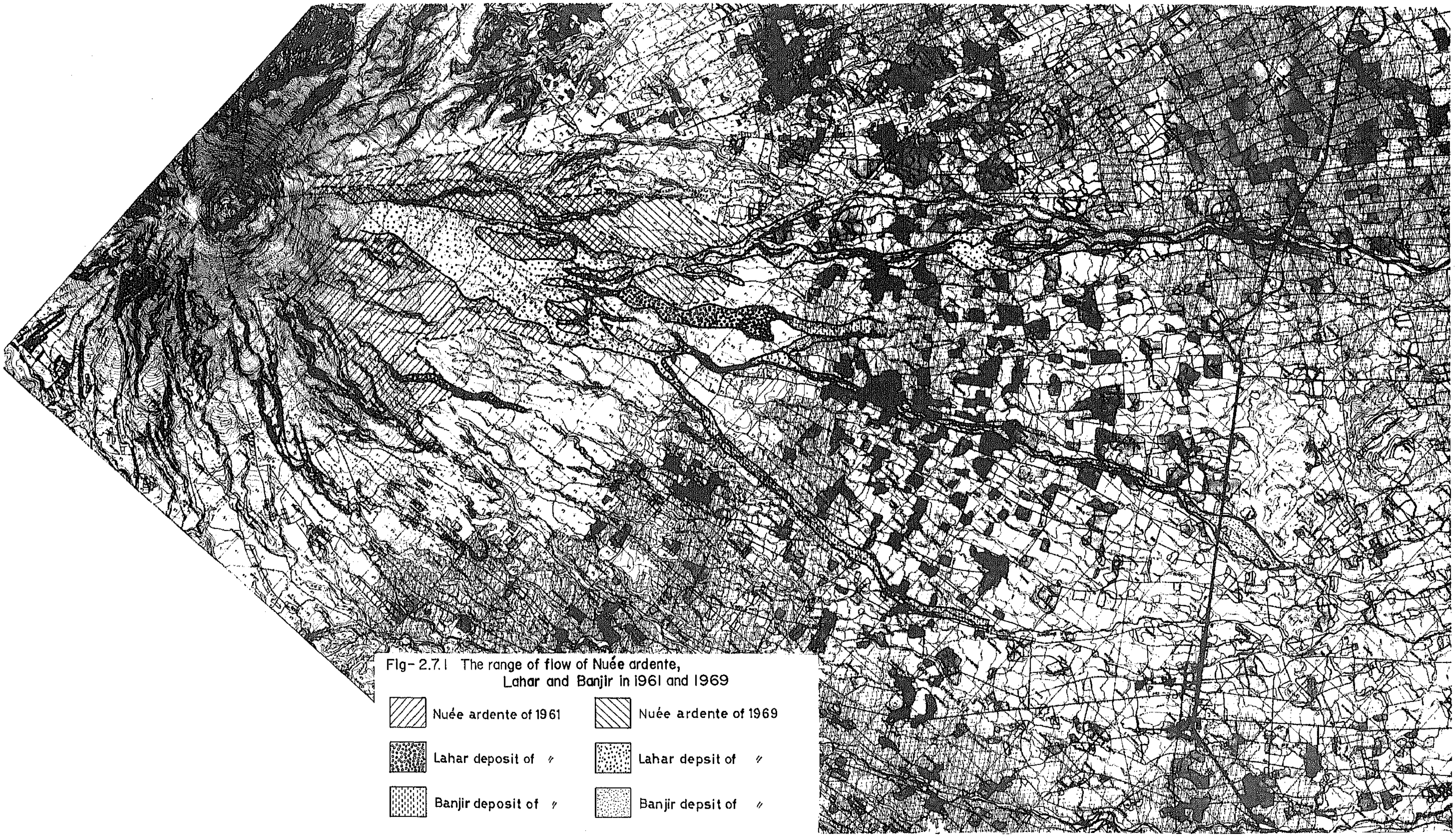


Fig-2.7.1 The range of flow of Nuée ardente, Lahar and Banjir in 1961 and 1969

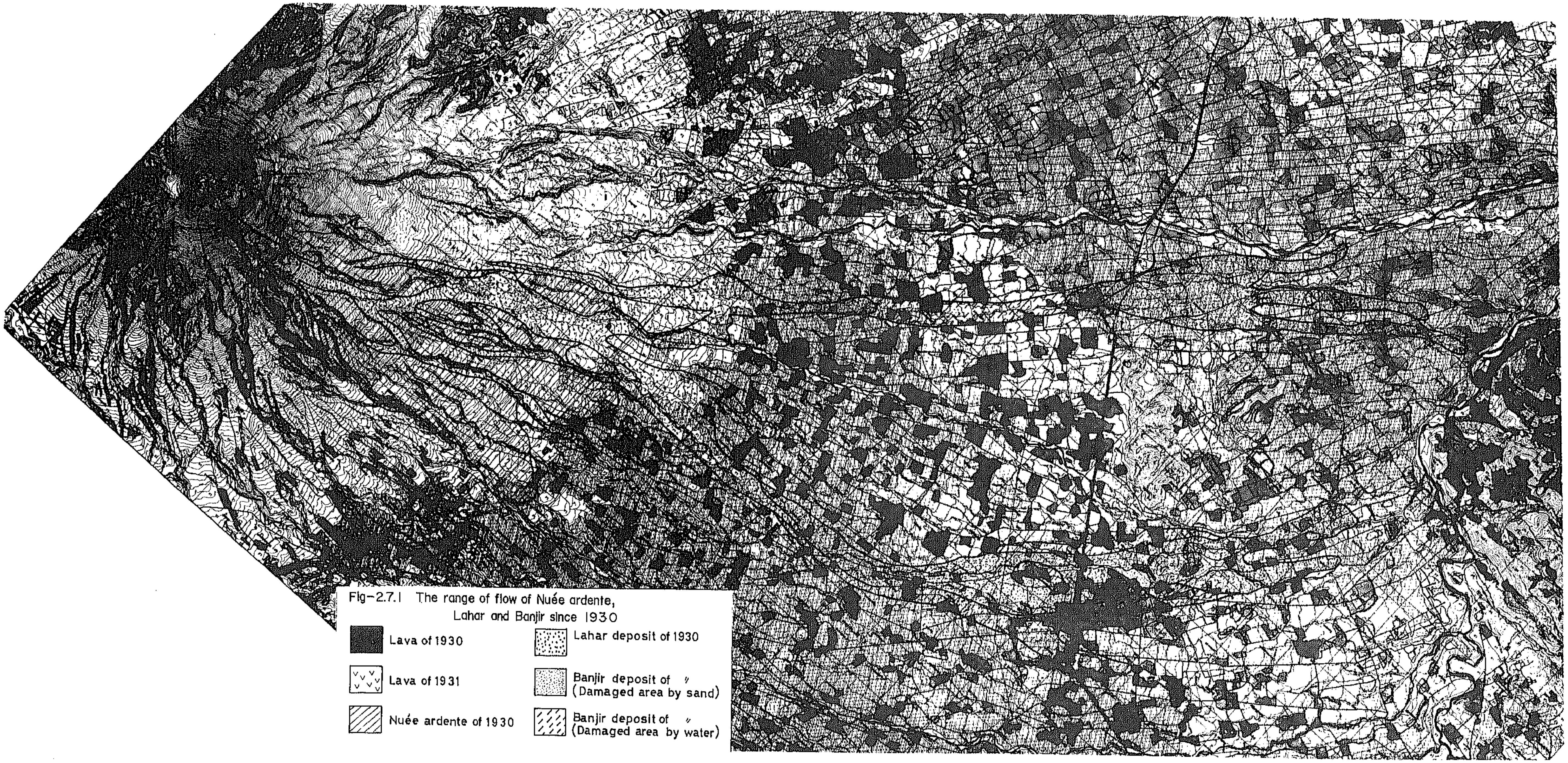


Fig-2.7.1 The range of flow of Nuée ardente, Lahar and Banjir since 1930