Review

REVIEW ON TRICKLE IRRIGATION APPLICATION IN GROUNDWATER IRRIGATION SCHEMES

Kajian Penerapan Irigasi Tetes Pada Jaringan Irigasi Airtanah

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ABSTRACT

The Government of Indonesia has developed groundwater irrigation schemes in some provinces e.g. East Java, Central Java, Yogyakarta, West Java, Bali, West Nusa Tenggara, and East Nusa Tenggara. However, not all regions were able to optimally utilize it. The irrigation efficiency of groundwater irrigation scheme was about 59%, while the wells-pumping efficiencies were varied from 28 to 98 %. In the future, the irrigation efficiency should be increased to anticipate water deficit during dry season. The application of trickle irrigation in Indonesia has not been widely developed. Although trickle system has been used, however, it is still limited for few commercial agribusinesses. Trickle irrigation systems have a prospect to be developed in some regions having limited water resources. For preliminary stage, the systems could be applied in groundwater irrigation schemes that have been developed either by farmers or government.

Keywords: *irrigation efficiency, trickle irrigation, groundwater irrigation schemes*

BACKGROUND

The Government of Indonesia has conducted effort to achieve food self sufficiency for rice through the development of irrigation schemes which include rehabilitation of existing irrigation networks, development of new irrigation infrastructures, and development of new rice fields. Today, there are more than 5 millions hectares of irrigated rice field, consisted of technical, semi technical, and simple irrigation schemes. However, there are still hundreds of thousand hectares of unutilized land spreads across Java and other islands that have not been developed, due to some reasons as follows :

1. The nature of the land (topographical and soil physical properties) which limit the development of surface irrigation systems
2. Unfavorable climatic condition such as areas that having more than six dry months
3. Limited of water sources

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The Government has also developed groundwater irrigation schemes in order to overcome those problems in some provinces e.g. East Java, Central Java, Yogyakarta, West Java, Bali, West Nusa Tenggara, and East Nusa Tenggara. However, not all regions were able to optimally utilize that. These are because the efforts were not accompanied with improvements in technology and management of farming system as well as irrigation system. In agriculture, water conservation is done by modifying drainage and watering systems and supported by optimum cropping pattern and on-farm water management.

Irrigation technology in developed countries has changed gradually in line with these problems. Open channel system changes to piping system. Surface system (basin, border, or furrow) changes to pressurized system (sprinkle or trickle). The efficiency of basin system in rice field in Indonesia was around 40-45%, whereas the furrow's was 60-65%. While the irrigation efficiency of that sprinkle system and trickle system was namely 75% and 90 %. In the future, the irrigation efficiency in Indonesia should be increased to anticipate water deficit during dry season.)

THE GROUNDWATER IRRIGATION SCHEMES

Technical Performance of the Groundwater Irrigation Schemes

The Republic of Indonesia Department of Agriculture has conducted a study on shallow groundwater development for small-scale farming in 1997. The study stated that the existing pumps operation is varied, depended on wells discharge and pumps size. The range of average pumps discharge based on wells discharge is about 1.9 l/s up to 6.8 l/s, while based on pumps size is around 4.5 l/s up to 6.5 l/s. The data of pumps operation is presented in **Table 1.**

Table 1. Pumps discharge (Q_p - l/s) in shallow groundwater irrigation schemes (case study in 25 kabupaten in Indonesia)

	Minimum	Maximum	Average
Wells discharge (l/s)			
<=5	0.9	3	1.9
5< Q_p<10	4.2	5.88	4.7
>=10	6	7.8	6.8
Pumps size (in)			
<=2	3	6.3	5.34
3	0.9	7.5	4.55
4	3.48	7.8	6.54

Source : Department of Agriculture, 1997

The irrigation requirements unit in shallow-groundwater irrigation schemes were determined according to the Oldeman's agro-climatic zones of the area. The value is about 0.66 l/s/Ha in type E zones, 0.99 l/s/Ha in type D zones, and 0.95 l/s/Ha in type C zones. The seasonal irrigation requirements for secondaray crops is around 336 – 379 mm. The actual application depth was, however, less than the requirement, as presented in **Table 2.** The study also stated that wells-pumping efficiency were varied about 28-98 %. This indicates that the wells capacity has not been pumped in an optimum level (Department of Agriculture, 1997).

The conveyance efficiency in shallow groundwater irrigation scheme with open channel system in Madiun was 91 %, while the application efficiency was 65 %, so that the irrigation efficiency was 59% (Harjoko, I.Y., 1998). The study of Prastowo and Nilmawati (2005) stated that the irrigation efficiency of shallow groundwater irrigation schemes in Nganjuk were varied about 49-81%.

The development of shallow groundwater irrigation schemes has already increased cropping intensity of

Table 2. Ratio of calculated water requirements (CWR) and actual application depth (AAD) with cropping pattern of paddy-paddy/palawija-palawija (case study in 25 kabupaten in Indonesia)

	Dry Season - 1 (MK-1)			Dry Season – 2 (MK-2)		
	CWR (mm)	AAD (mm)	Ratio (%)	CWR (mm)	AAD (mm)	Ratio (%)
Oldeman's Agroclimatic Zones						
C	356	152	36	461	351	51
D	379	150	44	445	143	40
E	336	160	84	104	87	83
Wells Discharge (l/s)						
<=5	151	32	52	311	91	51
5< Qp <10	375	102	26	566	107	18
>=10	423	214	56	393	258	58
Pumps Size (in)						
<=2	307	159	61	271	129	48
3	232	116	39	541	118	31
4	479	200	39	437	347	63

Source : Department of Agriculture, 1997

the planted area to about 200 – 300 percents. The cropping pattern was mostly *paddy-paddy/palawija-palawija/horticulture*. Irrigated command area were varied around 3–11 Ha. **Table 3.** presents the irrigated command of shallow groundwater irrigation schemes based on agro-climatic zones, wells discharge, and pumps size (Department of Agriculture, 1997).

Wells and Aquifer Characteristics

Wells may be classed as gravity, artesian, or a combination of artesian and gravity, depending on the type of aquifer supplying the water. Gravity wells are those which penetrate the water table where water is not confined under pressure. Wells, by far the most common, are either shallow or deep. Whenever the water level in a hole rises above the groundwater table, artesian condition are present. According to this definition, an artesian well is not necessarily a flowing well (Schwab *et al.*, 1981). Shallow wells, generally less than 15m in depth, are constructed by digging, boring, driving, or jetting (Todd, 1980). In Indonesia, potency of groundwater for irrigation mostly are located in East Java, and the command area is about 108,000 Ha or 64.3% of total area (national). About 61% of the shalow aquifer are developed using bored wells (Department of Agriculture, 1997).

The radius of influence given in **Table 4.** may be estimated from the texture and other characteristics of the aquifer (Schwab *et al.*, 1981). In Kediri, the radius of influence in shallow groundwater irrigation scheme was about 139 m. The study was conducted on a well with the transmissivity of the aquifer of 1405 m^2/day and the hydraulic conductivity of 94 m/day (Susatya, 1998).

Table 3. Irrigated command area (Ha) of shallow groundwater irrigation schemes with cropping pattern of paddy-paddy/palawija-palawija (case study in 25 kabupaten in Indonesia)

	Irrigated Command Area (Ha)		
	Minimum	Maximum	Average
Agro-climatic Zones			
C	3	17.8	8
D	4	37	10
E	3	5	5
Wells Discharge (l/s)			
<=5	3	10	3
5< Qp <10	5	37	11
>=10	3	19.5	9
Pumps Size (in)			
<=2	3	7	5.5
3	3	10	9
4	3	19.5	10

Source : Department of Agriculture, 1997

TRICKLE IRRIGATION SYSTEM

Trickle Irrigation Components

Trickle irrigation is a method of applying water directly to plants through a number of low-rate outlets generally placed at short intervals along small tubing. At these outlets specially designed orifices may apply water to individual plants or to a row of plants. Trickle irrigation, sometimes referred to as drip irrigation, is similar to watering a plant with a slowly leaking bucket. Unlike sprinkler or surface irrigation only the soil near the plant is watered rather than the entire area (Schwab *et al.*, 1981).

A trickle irrigation system discharges water close to each plant. Travel over the soil surface or through the air is of limited importance for distributing the water. The application uniformity basically depends on the uniformity of discharge from the emission devices (emitters). Thus, the design strategy for trickle irrigation systems focuses on achieving the desired emission uniformity. Trickle is an irrigation

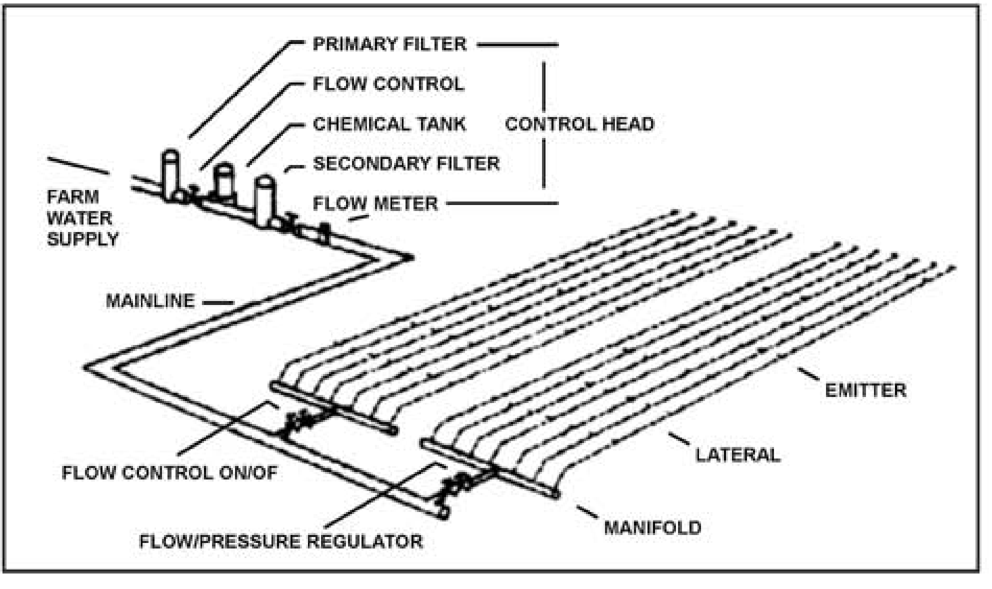

Figure 1. Schematically the basic components and layout of typical trickle irrigation systems (Keller and Bliesner, 1990).

Table 4. Radius of influence of wells

Soil formation and texture	Radius of influence	
	(m)	(ft)
Fine sand formation with some clay and silt	30 - 90	100 – 300
Fine to medium sand formation fairly clean and free from clay and silt	90 - 180	300 – 600
Coarse sand and fine gravel formations free from clay and silt	180 - 300	600 – 1000
Coarse sand and gravel, no clay and silt	300 - 600	1000 – 3000

Source : Bennison, 1947 after Schwab *et al.*, 1981

method that includes surface or subsurface drip, spray, bubbles, and hose-basin application techniques (Keller and Bliesner, 1990).

Component that are usually required for a trickle system include the pumping station, control head, main and sub-main lines, lateral lines, emitters, valves, fittings, and other necessary appurtenances. For all types of trickle systems, the laterals are connected to supply pipe lines called *manifolds*. **Figure 1.** shows schematically the basic components and layout of typical trickle irrigation systems (Keller and Bliesner, 1990).

Trickle Irrigation Planning Factors

Trickle irrigation systems are usually designed and managed to deliver frequent light application of water and to wet only a portion of the soil surface. Therefore, the procedures used for other methods must be adjusted to compute water and salinity-control requirements, irrigation depth, and frequency (Keller and Karmeli, 1974; Karmeli and Keller, 1975 after Keller and Bliesner, 1990).

Trickle irrigation systems normally wet only a portion of the horizontal, cross-sectional area of soil. The percentage wetted area, P_w, compared with the entire cropped area, depends on the volume and rate of discharge at each emission point, spacing of emission points, and type of soil being irrigated. P_w is determined from an estimate of the average area wetted at a depth of 150 to 300 mm beneath the emitters divided by the total cropped area served. A reasonable objective of design for widely spaced crops is to wet at least one-third and as much as two-thirds of the potential horizontal cross-sectional area of the root system, i.e., 33% < P_w < 67%. For straight single-lateral systems, the percentage wetted area can be computed as (Keller and Bliesner, 1990)

$$P_w = \frac{(N_p S_e W) \times 100}{(S_p \times S_r)} \qquad (1)$$

Where,

P_w : percentage of soil area wetted along a horizontal plane 30 cm below the soil surface

N_p : number of emitters per tree

S_e : spacing between emitters or emission points along a lateral line, m

W : the width of the strip that would be wetted by row of emitters, m

$S_p \times S_r$: tree spacing, m x m

Financial Analysis of Trickle Irrigation Schemes

Breakeven analyses are useful when one must make a decision between alternatives which are highly sensitive to a variable or parameter, and that variable is difficult to estimate. Through breakeven analysis, one can solve for the value of that variable or parameter at which the conclusion is a standoff. That value of the variable is known as the *breakeven point - BEP* (DeGarmo *et al.*, 1979). If nonlinear Revenue or Total Costs models are used, there may be more than one breakeven point (Blank and Tarquin, 1998). The study of Hadimoelyono and Prastowo (1997) shows the BEP of trickle irrigation application for secondary crops were varied around 8.4-59.6 Ha, whereas for vegetable crops were about 1.4-16.2 Ha.

The technique of discounting permits us to determine whether to accept for implementation projects that have variously shaped time streams and that are of different durations. The most common means of doing this is to subtract year-by-year the costs from the benefits to arrive at the incremental net benefit stream – the so-called cash flow- and then to discount that. This approach will give one of three discounted cash flow measures of project worth: the *net present worth*, the *internal rate of return*, or the *net benefit-investment ratio*. Another discounted measure of project worth is to find the present worth of the cost and benefit streams separately and then to divide the present worth of the benefit stream by the present worth of the cost stream to obtain the *benefit cost ratio.* Because the benefit and cost stream are discounted, the benefit cost ratio is a discounted measure of project worth. But because the benefit and cost stream are discounted separately rather than subtracted from one to another year-by-year, the benefit-cost ratio is not a discounted *cash flow* technique (Gittinger, J.P.,1982).

Design of Trickle Irrigation System

The design of a trickle irrigation pipe network may be based on the hydraulics of pipe flow. There are two irrigation efficiency terms that are affected by the system design : distribution and application. Distribution efficiency determines how uniformly irrigation water can be distributed through a trickle irrigation system into the field. An application efficiency shows how well irrigation water is applied, i.e., what percentage of water applied is stored in the root zone as required and available for plant use (Nakayama and Bucks, 1986).

It is necessary to know the efficiency of the irrigation system, so the relation between gross irrigation amounts and net additions to the root zone can be established. Emission uniformity is important, because it is one of the two components of irrigation efficiency; the other is various losses that occur during operation of the system. Emission uniformity can be calculated from the field test data by using equation below (Keller and Bliesner, 1990) :

$$EU' = 100\, q'_n / q_a \qquad (2)$$

Where,

EU' : field test emission uniformity, %

q'_n : average rate of discharge of the lowest one-fourth of the field data emitter discharge readings, l/s

q_a : average discharge rate of all the emitters checked in the field, L/s

The study of Apriliani (2005) shows that the application efficiency of trickle irrigation for tomato in hydroponics system was about 74-79%, whereas the uniformity was around 74-95%. While, Prastowo dan Widayanti (2003) stated that the irrigation efficiency of trickle irrigation for vegetable in DI Seropan was about 82-85%.

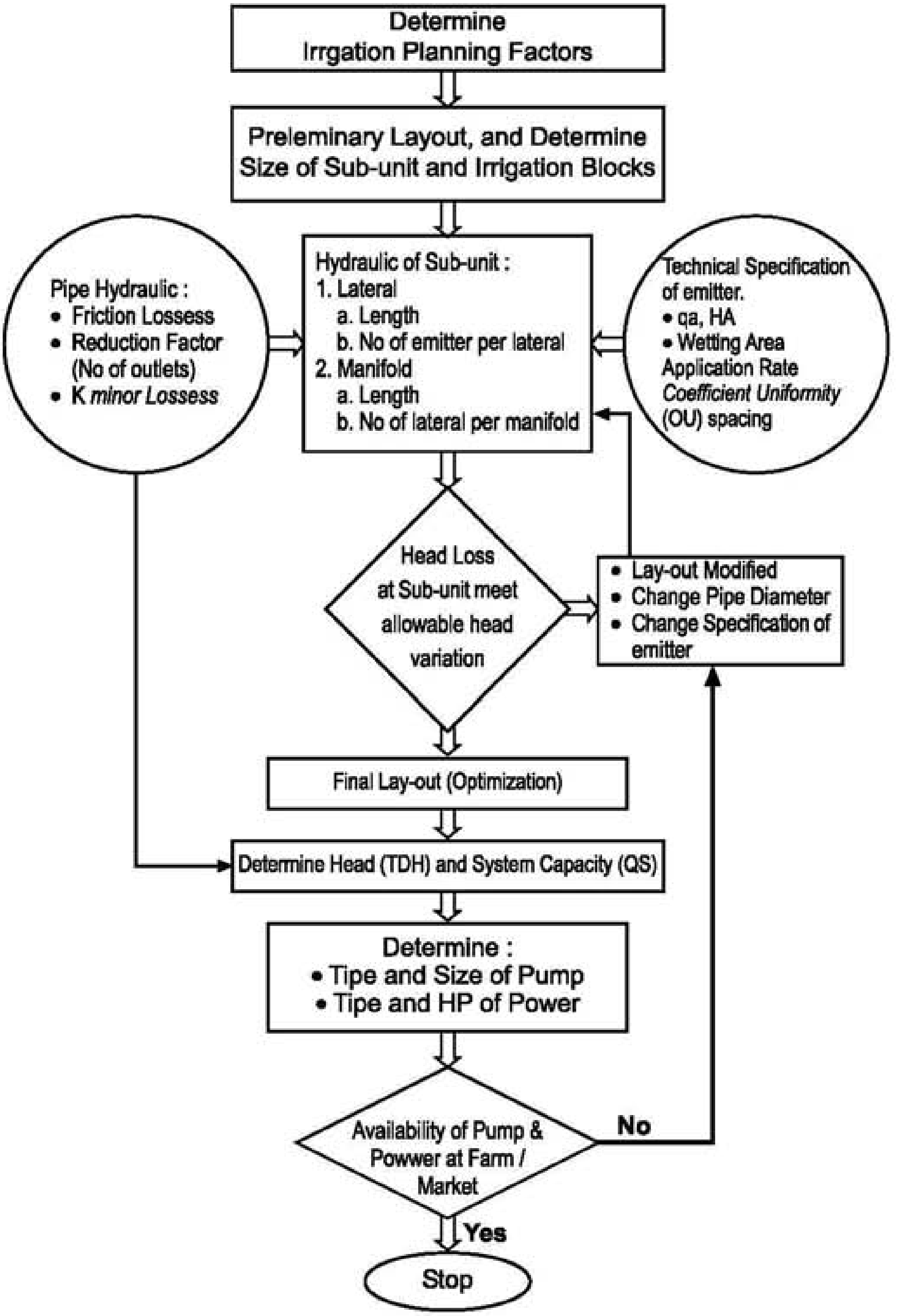

Figure 2. Design procedure of trickle irrigation (Prastowo and Liyantono, 2002)

The trickle design procedure has been developed by Prastowo and Liyantono, 2002 as presented in **Figure 2.** The procedure mentioned that by trial calculations of head loss at subunit, which has to be met to the allowable head variation, one could get the optimum size of manifold as well as lateral pipelines.

Of the many type of the pumps available, the centrifugal, propeller, and reciprocating pumps are by far the most common. From these three types, pumps may be selected for a wide range of discharge and head characteristics. A commonly used index of pump type is the specific speed. (Wijdieks and Bos. 1985.).

Trickle Irrigation Application in Indonesia

The application of trickle irrigation in Indonesia has not been widely developed. Although trickle systems has been used, however, its still limited for few commercial agribusiness. The use of trickle irrigation systems need support of right choices of crops, cropping period, and on-farm water management. Choice of commodity in many things is not free from market prospects, i.e. having high economic value and market guarantees.

The Government of Indonesia has given more attention to various non rice commodities not only which are able to support agro-industry (such as estate and secondary crops), but also have either domestic or overseas market chances. The Policies will become important factors in the application of trickle irrigation systems, because the system could be use as an alternative for :

1. Altering unutilized land having limited water becomes productive land
2. Increasing efficiency of utilization of water source which has been developed
3. Problem solving in competition of water utilization in the future

The Government has already conducted a study on the prospect of application of sprinkle and trickle irrigation systems in Indonesia in 1994. The results of the study stated that both systems have a prospect to be developed in some regions having limited water resources. For preliminary stage, the systems could be applied in groundwater irrigation schemes that have been developed either by farmers or government. Few limiting factors in the development of trickle irrigation system at farmers level are farmers' limited knowledge of technological, management, and financial ascpects.

The research on the development of design criteria of trickle irrigation in groundwater irrigation schemes, based on technical, management, and socio-economical aspects are very important, as a preparation to spread the system in the future. The research roadmap of the application of trickle irrigation in Indonesia is presented in **Figure 3**.

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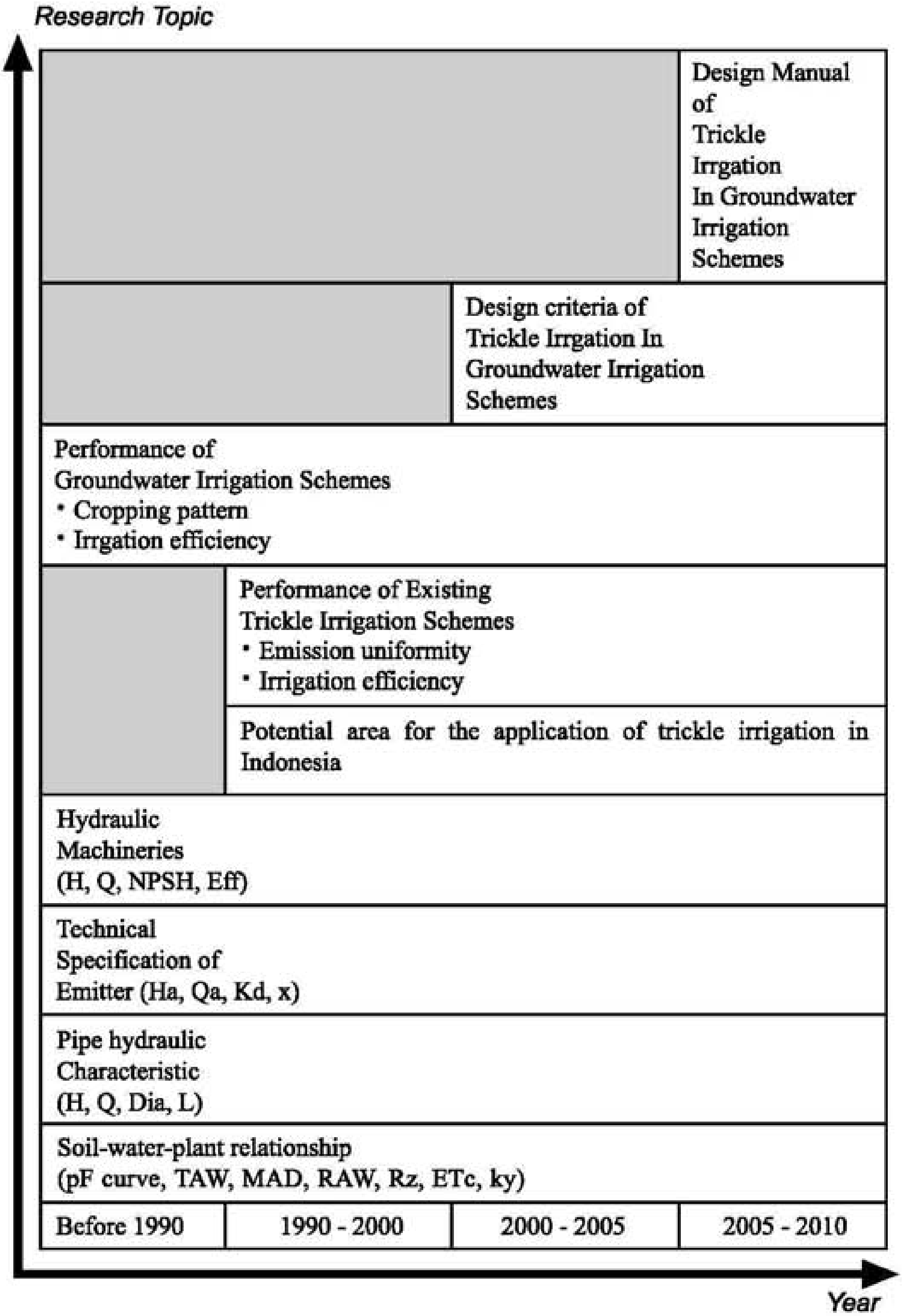

Figure 3. The research roadmap of trickle irrigation application in Indonesia