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Declining groundwater levels in India

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The decline of groundwater levels in India by 5–10 m is usually explained as a result of the increased number of tubewells and a decline in average annual rainfall. This article argues that the decline is the product of the destruction of indigenous systems for storing runoff water, which are essential because rainy days are very few and erratic. Futher, the disbanding of organizations concerned with indigenous systems for the management of natural resources, especially catchment areas, has weakened the ability to retain rainwater beyond the rainy season – another factor in the decline of India's groundwater levels.

The present decade in India has been marked by damage caused by a lack of rainfall on one hand and by flash floods due to heavy rainfall on the other. As soon as the monsoon is over, springs and streams start drying up and water scarcity haunts what was once the wettest spot on earth. When river catchments lose their hydrological functions, floods occur immediately following rain even when the rainfall is not heavy, leading to water scarcity during the rest of the year (Bandyopadhyay, 1987). The increased scarcity of water for all purposes is threatening all the country's so-called development works. With every passing year the budgetary allocation necessary to alleviate the effects of drought increases, to the detriment of other developmental activities in many areas.

In India the distribution of normal annual and monthly rainfall is largely determined by the physical features of the terrain, the configuration of mountains and plateaux, and the magnitude and time of onset of the monsoon. The very heavy rainfall zones are confined to the windward side of the Western Ghats, in the Brahmaputra valley and on the hills of Assam. The Bengal basin, Orissa, the eastern extremes of Madhya Pradesh and southeastern areas of the country are receivers of heavy rainfall (over 1700 mm). The rest of India experiences low rainfall, ranging between 750 and 1000 mm. The western parts of Rajasthan, adjoining the desert, receive only 350 mm of rainfall.

It is in these low rainfall regions that human survival is threatened today due to the scarcity of water. In these regions the number of endangered villages, where even drinking water is hard to get, is increasing every year. For example, during the 1960s in Uttar Pradesh 17 000 villages were without water for drinking; similarly, in Maharashtra 23 000 villages were facing a scarcity of water in 1984; in Gujarat the number was 64 565 in 1985; in Karnataka, where a campaign to extend drinking water facilities to every village was launched on a war footing in 1984, there were 655 villages without water to drink.

Explaining the decline

There is an urgent need to understand the various factors that are contributing to the depletion of groundwater, and especially why drinking water has become scarce. Moreover, apart from the dearth of drinking water, it is becoming very difficult for small and marginal farmers to tap groundwater for

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irrigation purposes. The average area serviced by each well is decreasing in spite of the use of powerful pumps (Paul, Wim and Willey, 1988). In Kolar district of Karnataka, known for having the greatest number of energized pumpsets (59 248), the area irrigated by wells has declined from 67 391 ha in 1970/71 to 47 788 ha by 1984/85. Similarly, in Coimbatore and Periyar districts of Tamil Nadu, and in the Rayalaseema region of Andhra Pradesh, there has been a decline in the area irrigated by wells. According to one source, the groundwater level in the country as a whole has declined by 10 m (CMIE, 1988); in the states of the Southern Peninsula the decline is far more serious than in the Gangetic belt.

This decline has been attributed to the increased number of wells and the appearance of powerful energized pumpsets (Chaturvedi, 1987). The increase in the number of tubewells has also been cited as a factor (Jayal, 1987). But what has been forgotten is the fact that tubewells came onto the scene at a time when groundwater levels had already declined beyond the reach of dug wells. Therefore the large-scale sinking of tubewells in a region is a reflection of the declining groundwater levels in that particular region, rather than the other way round, although the compressors and powerful pumps in each tubewell have hastened the process of decline.

The decline in groundwater levels, especially beyond the reach of dug wells, has to be examined in a geoecological and social management perspective, and not merely as a result of the increased number of wells. The area irrigated by dug wells at the national level has remained at about 8 million ha since 1980/81 whereas the percentage area irrigated by wells has declined over the years (see Table 1). In Kolar district of Karnataka the number of energized pumpsets has increased from 34 104 in 1970/71 to 59 428 by 1984/85 whereas the area irrigated by wells has declined from 67 391 to 47 788 ha. Such an increase in the number of wells and pumpsets on the one hand and decrease in the area irrigated by them on the other has affected the ability of farmers to irrigate their land more than once. In Kolar this figure has decreased from 29 463 ha in 1970/71 to 3434 ha in 1984/85. Similarly, in Ananthapur and Cuddapha districts of Andhra Pradesh and Coimbatore and Periyar districts of Tamil Nadu, there has been a decline in the area irrigated more than once

Table 1. Sources of irrigation, 1950/51–1982/83, in million ha (percentages in brackets).

	Canals Government	Private	Tanks	Wells Tubewells	Dug wells	Other sources	Total net irrigated area
1950/51	7.2 (34.5)	1.1 (5.2)	3.6 (17.2)	—	6.0 (28.7)	3.0 (14.4)	20.9 (100.0)
1960/61	9.2 (37.1)	1.2 (4.8)	4.6 (18.6)	0.2 (0.8)	7.2 (29.0)	2.4 (9.7)	24.8 (100.0)
1970/71	12.0 (38.5)	0.9 (2.9)	4.1 (13.1)	4.5 (14.4)	7.4 (23.7)	2.3 (7.4)	31.2 (100.0)
1975/76	12.9 (37.3)	0.9 (2.6)	4.0 (11.6)	6.8 (19.7)	7.6 (22.0)	2.4 (6.8)	34.6 (100.0)
1976/77	13.0 (37.0)	0.8 (2.3)	3.9 (11.1)	7.4 (21.1)	7.7 (21.9)	2.3 (6.6)	35.1 (100.0)
1977/78	13.7 (37.5)	0.8 (2.2)	3.9 (10.7)	7.6 (20.8)	8.0 (21.9)	2.5 (6.9)	36.5 (100.0)
1978/79	14.3 (37.5)	0.8 (2.1)	3.9 (10.2)	8.2 (21.6)	8.3 (21.8)	2.6 (6.8)	38.1 (100.0)
1979/80	13.9 (36.2)	0.8 (2.1)	3.5 (9.1)	9.3 (24.2)	8.5 (22.1)	2.4 (6.3)	38.4 (100.0)
1980/81	14.5 (37.4)	0.8 (2.1)	3.2 (8.3)	9.5 (24.5)	8.2 (21.0)	2.6 (6.7)	38.8 (100.0)
1981/82	14.7 (37.0)	0.8 (2.0)	3.5 (8.8)	9.9 (24.9)	8.2 (20.7)	2.6 (6.6)	39.7 (100.0)
1982/83 (provisional)	14.8 (37.1)	0.5 (1.8)	3.1 (7.8)	10.7 (26.8)	8.4 (21.0)	2.4 (6.0)	39.9 (100.0)
Annual rate of increase (%) between 1950/51 and 1982/83	2.3	−2.4	−2.5	19.8	1.1	−0.7	2.0

Table 2. Meteorological and hydrological drought years in Kolar and Ananthapur districts.

	Kolar		Ananthapur	
	Hydro-logical	Meteoro-logical	Hydro-logical	Meteoro-logical
1951–60	5	4	5	—
1961–70	6	4	5	1
1971–80	2	1	4	1

Source: Central Water Commission, *Drought Studies in Drought-Prone Regions of South India*, Government of India, New Delhi, 1980.

by wells. This decrease is usually regarded as a consequence of too many wells. But why in that case should similar declines also be found in areas where the density of wells or the area irrigated by wells is very low? How can this explanation cover what is a universal phenomenon throughout the country? Such a universal decline in the levels of groundwater has to be examined in the light of the recharge capacity of each region and the causes for its decline.

At the grassroots level the owners of wells consider that it is the lack of rainfall which has caused the lowering of groundwater levels. An examination of the rainfall pattern in districts where there has been a drastic decline in groundwater shows, however, that the rainfall, especially in the monsoon season, has not been as erratic as claimed and that the deviation from the norm has not been very great. A study of Kolar district conducted by the Central Water Commission shows that over the 30-year period 1951–80 there was a meteorological drought, wherein the rainfall is below 75% of normal, in only nine years. Similarly, Ananthapur district had only two years of meteorological drought in 30 years (Table 2). A similar situation was found in Cuddapha and Kurnool districts of Andhra Pradesh, and Bangalore, Chitradurga and Raichur districts of Karnataka. Therefore, even the belief that frequent droughts and high deviations in rainfall are causative factors in the decline of groundwater levels has to be questioned.

Hydrology and geology of Karnataka

Such a conclusion assumes further strength if rainfall throughout Karnataka is taken into consideration. A study by the Directorate of Economics and Statistics of the Government of Karnataka (DES, 1984) reported only a one-point deviation in the normal monsoon rainfall, which provides 73% of total rainfall, while 16% of the rainfall is contributed by the late or southeast monsoon (Table 3). More than 70% of rainfall occurs during the four months June–September, and in fact it is concentrated in a few hours over 25–70 rainy days (Singh, 1984). The DES study reported a deviation of 41% in rainfall during January–February, which are cold months (see Table 4), but since agricultural activities are synchronized almost entirely with the southwest monsoon rains, the impact of this deviation in the cold weather period can be regarded as insignificant. On the other hand, between 1962 and 1981 there was very little variation in rainfall levels during the agriculturally critical wet season. It can therefore be concluded with confidence that the decline in the level of groundwater is not related to deviations in normal rainfall.

The high concentration of rainfall in four months means that groundwater recharge must overwhelmingly take place during this period of the year. If the necessary level of recharge is to be attained, this must be done during the high-rainfall months. There is thus a need for a host of mechanisms for retaining more rainfall in these four months than can be immediately absorbed into the soil. The number of such mechanisms required is directly related to the type of soil and its percolation rate, the geology of the given area and the maximum and minimum temperatures found there.

Table 3. Normal rainfall pattern according to the seasons in the state of Karnataka.

Seasons	Months	Average quantity of rainfall (in mm)	Percentage of annual total
Cold weather period	January and February	8.3	1
Hot weather period	March to May	142.3	10
Southwest monsoon	June to September	991.7	73
Southeast monsoon	October to December	212.4	16
All seasons		1354.7	100

Table 4. Seasonal pattern of average annual rainfall, 1962–81, in the state of Karnataka.

Seasons	Months	Normal rainfall (in mm)	Average rainfall (in mm)	Percentage departure from normal
Cold weather period	January and February	8.3	4.9	(−) 41
Hot weather period	March to May	142.3	147.7	(+) 4
Southwest monsoon	June to September	991.7	979.3	(−) 1
Northeast monsoon	October to December	212.4	204.7	(−) 4
All seasons		1354.7	1336.6	(−) 4

Table 5. Climatic water balance (in mm) of Karnataka.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Precipitation	86	88	118	167	155	152	90	125	114	120	88	72	1375
Potential evapotranspiration	6	4	9	32	57	165	294	233	159	123	45	7	1134
Actual evapotranspiration	45	31	30	46	63	152	90	125	114	120	84	52	952
Water deficit	41	57	88	121	92	0	0	0	0	0	4	20	423
Water surplus	0	0	0	0	0	0	26	108	45	3	0	0	182

The geology of the Southern Peninsula, unlike the Gangetic belt, is mostly composed of grey granite stones of a category called Deccan trap. Since it is very hard, water can only reach the storage areas below through secondary features such as joints, weathering, fissures, etc. The slow movement of water through joints and fissures places an additional demand on the soils of the area to store water for a long time in order to replenish the groundwater to its normal level. As the joints and fissures do not occur uniformly the reservoir space becomes disjointed and small pockets of water form (Jaglab, 1984; Maggarwar, 1984). In order to replenish the stock in these small pools, the soils are required to hold water for longer than their natural capabilities to enable the rainwater to move through schists to reach the storage points.

The normal temperature in a given day being above 40°C in most parts of South India, the monthly evaporation rate normally ranges between 30 and 125 mm. The annual evaporation is 952 mm (Narendra Prasad). With such high evaporation, the capacity of soils to hold moisture for percolation purposes has to be high. Unfortunately, black cotton soils predominate in the peninsula. The annual deficit in water-deficient months is calculated to be 423 mm (Table 5). Unless the heavy rainfall in the months from June to September is held back trom getting to the sea, the soils on their own are incapable of recharging the groundwater levels.

Traditional conservation methods

Understanding the various limitations the soils have and the constraints set by geology, the civilizations that had lived in this area have developed mechanisms for replenishing the groundwater. These mechanisms are known as tanks, and they are found in almost all low-rainfall, arid and semi-arid regions of the Southern Peninsula. In fact, the three states of the peninsula exceed all other states in India in the number of tanks they possess (Table 6).

The popular definition of a tank is a 'small water reservoir created by throwing an embankment of earth across the flow of water' (Sharma, 1981). The embankment may be between two raised areas of ground or it may take a concave form in which the extremities are stretched sufficiently to retain the depth of water required in the belly of the curve. But this definition limits the scope of the term to a description of part of the system. We must take into consideration the system as a whole, and in this sense the tank is not simply a reservoir or an area of water, but extends beyond the water-covered area into the catchment and the area irrigated by the tank. Such a comprehensive definition is required to understand the role of a tank not only from the point of view of irrigation, which is certainly one of its aspects, but also as a source of water conservation, especially in recharging groundwater.

Tanks are built in a chain, and size predominantly determines the order of succession. The surplus water from one tank moves into the succeeding tank until the entire chain terminates at the beginning of a river or empties into a river. As each tank is fed by a preceding smaller tank, focusing on a single unit does not bring out the role of tanks in the conservation of rainwater for percolation purposes.

Tanks are predominantly found in those parts of India where rainfall is below 750 mm and where

Table 6. Sources of irrigation (% of net irrigated area) in various states of India.

	Canals	Tanks	Wells	Others
Assam	63	—	—	37
Andhra Pradesh	47	28	22	3
Bihar	41	—	59	—
Gujarat	19	—	79	—
Karnataka	42	20	27	11
Kerala	39	14	12	35
Maharashtra	21	15	58	6
Madhya Pradesh	44	4	44	8
Orissa	64	17	19	—
Punjab	41	—	59	—
Haryana	54	—	37	—
Rajasthan	34	7	58	—
Tamil Nadu	33	31	35	—
Uttar Pradesh	34	2	61	3
West Bengal	37	14	36	13

Source: CMIE. *Basic Statistics Relating to the Indian Economy*, Vol 2, 1988.

every drop of rain has to be conserved within the soil for the purpose of raising good crops. In such areas every drop conserved is a step towards the conservation of groundwater. In such a situation the ability to irrigate is chiefly a function of the optimum level required for replenishing groundwater. When replenishment is below the optimum level, the irrigation potential of a tank tends to be low or totally absent. In order to enable the tanks to replenish groundwater to the optimum level, devices more or less similar to tanks in physical structure, but of a smaller size, were built into the system of tanks. Each tank had such a device incorporated into it. Such devices are known by various names in southern India. In Tamil Nadu they are called *pallam*, *madavu* and *kuttai*. In Kannada-speaking Karnataka they are called *kunte* and *katte*. In Telugu-speaking Andhra Pradesh they are called *kunta* and *katta*. The Telugu, Tamil and Kannada terms are almost equivalent; literally they all mean a pit to hold water flowing from a few fields. When flooded, the water from these fields leads to a single *katte*, *katta* or *madavu*. With the exception of *kunte* or *kunta*, these pits serve areas ranging from a few acres to several hundred in rare cases. Even today, many of the *kattes* in the drought-prone Karnataka districts of Raichur, Bellary, Gulbarga and Bijapur irrigate hundreds of acres. Several of these *kattes*, when they overflow, lead into a particular tank, which is called *cheruvo*, *kere* and *kattai* or *cheri*. So these structures are conservation points for water at different levels in the catchment area. By holding back the runoff at each point they protect the soil from erosion and help to infiltrate water into the soil. In short, any attempt to define tanks has to take into consideration these mechanisms built exclusively for the conservation of water. In this sense a tank can be defined as a technology for the conservation and utilization of runoff water for percolation and irrigational purposes.

The tank, as a physical unit, includes all the mechanisms for drawing water and the provisions for surplus water, the water-covered area, the catchment and the command area. All the elements which may lead to a succession of tanks are included. The embankment is the physical structure which withholds the water in the water-covered area. The size and shape of embankments differ according to the type of soil, the topography and the order of the embankment in the series. Those which are very small and perform only conservation activities, as in the case of *kunte*, will be semicircular in shape, facing the water. They may be a few feet in height. They will have no stone revetments on the side facing the water. Plants or shrubs of proven ability to hold together soil against the standing water may have been planted on the side of the bund facing the water. In the case of *katte*, the embankment will once again be a semicircle, but it will have a stone revetment on the side facing the water. If the water impounded is beyond the optimum conservation level, water may be drawn off to irrigate a few acres of land. A sluice of appropriate size and shape may be provided at a suitable point so that the last drop of stored water can be drawn out. In tanks, too, the embankment will have a stone revetment and sluice. The number of sluices provided depends on the quantity of water stored and the area to be irrigated.

Tanks can be classified as small, medium and large. Tanks or *keres* to which few *kattes* provide water will normally be small. A number of smaller tanks feed a medium tank and many medium tanks may contribute to a large one. Normally, the large tank will be rather like a small reservoir, capable of irrigating thousands of acres and it will either empty its surplus water into a stream or tributary, or it may give rise to a stream of its own. These are called terminal tanks.

The function of these *kunte*, *katte* and tanks is not limited to the conservation of water. Though this may be a major function, the other objectives are to prevent soil erosion and the flow of silt into bigger tanks. As *kuntes* are traditionally located at every strategic point between fields in the catchment, the water never has a chance to flow as a single course for a long distance. Periodically *kuntes* are sited to check the free flow of water, reducing the velocity of flow and retarding erosion. Runoff water is made to oveflow the *kuntes* to settle and shed all its sediment load. *Kattes* play a more or less similar role of checking runoff water and the huge quantities of silt carried by it.

The built-in mechanism for shedding silt at various strategic points is helpful in desilting, as the quantity collected at each point is small and within the capability of a few farmers to desilt every year. Regular and repeated desilting has kept these mechanisms in operation over a long period.

Not only will the foreshore area of a tank slope gently towards the centre but certain measures are taken to prevent silt flowing into the tank. The usual measures are to provide tree cover which can withstand submersion either partially or fully and pits of various sizes in sucession. These are silt traps to prevent the flow of silt into the tank. If water flows into the tank from various directions then at each point such mechanisms are provided. The number of trees and silt traps depends on the size and location of the particular tank in the series. Normally, the one at the beginning of the series has many. But each tank has its own independent catchment area apart from being fed by the tanks upstream. Depending upon the size of the independent catchment, more or fewer silt traps are provided. In black cotton soils the number of silt traps in the form of pits is large. If the catchment is cultivated, silt traps are provided for every field as the quantity of silt carried by runoff water is high. In addition, at suitable points *kuntes* and *kattes* are built not only to trap silt but also to infiltrate water into the soil.

Tanks may be of two types: percolation and irrigation, though the categorization is not a rigid one. Tanks' function is highly dependent on the soils in which they are built. In black cotton soils most of the tanks are percolation tanks as the soil's percolation capability is very low; this is the case, for example, in Raichur district. The tanks here are shallow and irrigate only during the summer months, and then only a limited area. Similarly, in Ananthapur district of Andhra Pradesh percolation tanks predominate, especially very small ones.

Administering a tank system

The effectiveness of a tank as a recharger of ground-water depends greatly on its storage capacity, its extent and the efficiency with which the stored water is used. Traditionally a tank is the property of an entire village community. A committee normally called a *panchayat* in Karnataka and Andhra Pradesh and a *kudimaramatts* in Tamil Nadu is charged with the responsibility for effective utilization. These committees decide the quantity of water to be released on the basis of the water stored in the tank. The time intervals between each release of water and the crops to be grown to make effective use of the released water are determined by the *panchayat*. To implement such decisions, the *panchayat* has an official called a *nirganti*. Groups of *nirgantis* (in the case of tanks irrigating large areas) are supervised by a member of the *panchayat* known as a *hirekara*.

Wherever the *panchayats* are effective, the levels of groundwater have been maintained to this day. In and around Tallaku village in Chitradurga district, Karnataka, natural springs abound as a testimony to well-maintained groundwater levels. Tallaku receives an annual rainfall of 395 mm and might have been expected to have reeled under drought for seven years from 1980/81 to 1987/88. But in Tallaku three natural springs irrigate an area of 25 ha; two tubewells sunk by the state government irrigate a further area of 75 ha.

In another drought-prone district of Karanataka, Tumkur, the villages of Gattalogollahalli have been able to maintain good groundwater levels by effectively utilizing the water stored in their tank. Two natural springs irrigate 175 ha of command area, especially in the summer months. Another three springs irrigate about 23 ha.

In Hosadurga and Hollalkere Taluk, in Chitradurga district, even with a rainfall as low as 355 mm farmers are able to grow coconuts by constantly maintaining the soil moisture. Normally, the water stored in the tanks is not drawn for irrigation purposes unless and until extreme circumstances call for such action. The fact that water is stored throughout the year has enabled the coconut plantations to survive in this arid zone. Similarly, in Tallaku and Gattalagollahalli storage is given more prominence than utilization. Whatever water is collected will be released for use only when it is beyond storage requirements at least until January. The month of January is very precious, as a big festival called 'Sankranthi' is held then, normally on the 14th. The festival symbolizes the end of the agricultural season for that year; functionally it is taken as the point up to which water has to be stored to make it available for percolation. The rationale usually given for this is that the water is required to feed the cattle in the summer months.

Destruction of the system

At least in the Southern Peninsula, every tank used to have a *panchayat* to regulate the utilization of the stored water. But due to the withdrawal of the royal patronage extended to them for physical maintenance by the British and the replacement of traditional administrative systems by elected representatives and bureaucrats, the *panchayats* have frequently been disbanded. The introduction and encouragement of various exotic commercial crops has also changed the entire cropping pattern of the command areas of tanks. These interventions have disrupted the highly evolved individual systems of water management by undermining the uniformity and proportionality of water distribution. In the areas where the *panchayats* have been disbanded, groundwater levels have dropped very considerably.

In Mallur village of Kolar district in Karnataka there are three tanks with a capacity to irrigate 32, 62 and 150 acres, a total of 244 acres. Until 1965 each tank was able to provide water for two crops of paddy. With the abolition in 1965 of hereditary village revenue officers and the headman, who were also the leading members of the *panchayats*, this traditional water management system was also disbanded. As a consequence, even in spite of good

Table 7. Rainfall and paddy crop under tank irrigation in Mallur village.

	Rainfall[a] (mm)	Paddy crop[b] (acres)
1965	451.6	40
1966	1045.1	180 (two crops)
1967	788.5	80
1968	643.8	65
1969	882.3	84
1970	788.3	78
1971	836.6	82
1972	726.2	68
1973	867.5	96
1974	693.2	32
1975	637.2	30
1976	742.7	55
1977	1004.4	85
1978	684.5	31
1979	789.4	33
1980	482.6	No crop
1981	763.4	38
1982	663.6	32
1983	783.8	33
1984	648.6	30
1985	451.4	No crop

[a]Normal annual rainfall is 733.4 mm.
[b]The maximum area that can be irrigated with paddy is 244 acres.

rainfall over several years (see Table 7), indeed even when there has been above-average rainfall, the tanks have overflown but farmers have not been able to grow even a single crop of paddy due to mismanagement of the water. A similar fate awaits the tank in Kunigal: even though this tank has the capacity to irrigate 2000 acres, because of the disappearance of the *panchayat* and *nirganti* tail-enders, who account for nearly 200 acres, have converted their paddy-growing fields into rainfed agriculture. Only one crop can be harvested instead of two.

Madure tank in Bangalore district has a water-spread area of 465 ha; the command area is 288 ha. From 1965 onwards, due to the suppression of the *panchayat*, the ability to grow even one substantial crop has been lost (Table 8). As a consequence the majority of landowners have gone in for plantation crops such as casurina and eucalyptus.

Table 8. Crops grown in the command area of Madure tank (ha).

	1965/66	1970/71	1975/76	1980/81	1985/86
Paddy	255.6	226.2	188.4	95.3	36.7
Sugarcane	0.1	4.2	2.4	—	—
Ragi (irrigated)	7.3	22.9	36.3	43.4	50.4
Jowar (fodder variety)	3.3	—	10.2	15.3	47.5
Betelnut	10.4	8.3	—	—	—
Casurina	—	20.4	48.5	135.6	155.5
Fallow	—	6.0	3.0	—	—

Tanks are very important as far as catchment areas are concerned. The quantity of water stored and the longevity of the tank is directly related to the status of the catchment area. Recognizing the importance of catchment areas, they were traditionally declared to be property belonging to the entire village community. If the catchment area was very big and spread over several kilometres, only flat lands were cultivated; the slopes were always protected from cultivation. Such protected catchments were reserved for pastures, and abundant tree growth was always encouraged. As such catchment areas were the property of the community, every individual, irrespective of caste and class, had a right to graze cattle and also to collect firewood and timber from dead and fallen trees. Usage was also regulated by the *panchayat* in the event that a particular activity would have caused harm to the trees. In certain places animal droppings were not collected as they were an essential requirement for the regeneration of grasses. Fruits of various kinds were auctioned to collect the required sum to enable the physical maintenance of the tank.

Understanding the importance of catchment areas to the proper functioning of tanks, the pre-colonial rulers, and even the British up to the 1940s, recognized the usufructory rights of each village community which managed the catchments within the boundaries of that village. No tax was levied on such catchments nor did the administration interfere with the village management. But this sensitive attitude did not survive beyond the 1940s. Due to the expansion of the urban and industrial population of India after the second world war and the consequent shortage of food grains, the government was compelled to expand the cultivated area of the country. At village level this expansion was possible only by bringing catchments into cultivation. This not only undermined the rights of the community over the catchments, but it also alienated them from the usufructory rights that they had over the catchments. Such alienations affected the control exercised by each *panchayat* in managing the resources available and the catchment areas as such. Along with the weakening of community control came a huge demand for land to cultivate from all sections of the rural population. When it transpired that government allocations were benefiting only the rich landlords, in the 1960s the Communist Party sponsored a 'land grab' movement. In response the government introduced a new policy called 'land to the landless'. In the name of this policy entire catchments were distributed. Nearly 43 million ha of land were dispersed between 1950/51 and 1983/84. In consequence of such a large-scale distribution in the absence of any preconditions concerning soil conservation, the rates of erosion from catchments rose, bringing about the siltation of tanks. Those that were small and at the head of a chain of tanks were the first and worst affected. Today nearly 36 000 tanks in Karnataka, each with the capacity to irrigate 100 acres or less, have been lost due to siltation. The consequent reduction in the area irrigated by tanks can be imagined. In 1956 tanks in Karnataka irrigated an area of 3.28 lakh ha, but in 1984 the area so irrigated had shrunk to 2.93 lakh ha.

The cultivation of catchment areas has affected most of the other mechanisms that were directly helpful in recharging groundwater. Of these, *kattes* and *kuntes* have been the worst affected. *Kattes* and *kuntes* were frequently ploughed in when their catchments were brought under cultivation or when the community lost control over them. The consequence of such destruction has been the flow of silt directly into the tanks. As a result most of the tanks at the head of chains have silted up. In Karnataka nearly 31 970 tanks which irrigate between 10 and 50 acres have been hard hit. The consequences for groundwater recharge have been enormous. Once the mechanisms for detaining water at various strategic points have been destroyed and the tanks have silted up, the amount of water percolating into the soil is limited to the period of heavy rainfall. As a consequence, groundwater has been recharged far less quickly than it has been extracted in districts where wells predominate. In Kolar district of Karnataka there are about 3825 tanks irrigating nearly 64 111 ha of land. Of those 3825 tanks 3320 used to irrigate between 10 and 50 acres. Today most of these tanks have silted up. As tanks became redundant the number of wells gradually increased – from 37 670 in 1970/71 to 58 249 in 1984/85. Today more than 15% of these wells have been abandoned and the area irrigated by wells has been reduced from 67 391 ha in 1970/71 to 47 188 ha in 1983/84. This amply proves that the decline in groundwater levels in the arid zones of India is due to the destruction of tanks which had played a significant role in recharging them.

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