Food and Agriculture Organization of the United Nations

Efficient agricultural water use and management in paddy fields in **Sri Lanka**

NATIONAL OUTLOOK

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Foreword

Rice and rice-based products are a staple food and the primary crop grown by farmers in Sri Lanka. In addition to the contribution to national food security, they also constitute a major social and economic activity, providing public goods and a key source of employment and income for the rural population.

Irrigation systems in the country were essentially developed for paddy cultivation. Currently, water provision at national level is ensured by are 230 man-made major and medium irrigation reservoirs, 12 000–15 000 minor irrigation reservoirs and 103 natural river basins. Water resources available in these systems are extracted and employed for the development of irrigation, water supply, hydro–power, industrial uses, and other economic uses. Occasionally, Sri Lankan farmers also use groundwater to irrigate paddy fields.

Water resources management and irrigation is vital for the economic development and social well–being of Sri Lanka. Paddy field systems are especially water demanding. Currently, about 80 percent of paddies is irrigated. Out of the total energy generation, 35 percent is from hydropower. About 4 percent of the population is currently receiving the pipe–borne water while the provision of a safe and adequate amount of water for drinking remains a challenge. In view of the projected water demand, increased water use efficiency in irrigation is crucial to increase agricultural productivity sustainably.

The project "Efficient Agricultural Water Use and Management Enhancement in Paddy Fields", funded by the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF), is designed to increase the understanding of the status of water use efficiency and water productivity in Sri Lanka and Zambia, identifying both limits and potentials at national level.

The National Outlook on efficient agricultural water use and management enhancement in paddy fields provides the status of water use efficiency in paddy fields and agricultural water productivity in Sri Lanka. It identifies the irrigation potentials, gaps and needs that exist at national level for paddy rice production. The Outlook addresses all stakeholders involved in the sector, including farmers, technicians, researchers, extension agents and decision–makers. We hope all of them, as well the readers outside of the country, will find the Outlook a useful information source and directly or indirectly benefit from the discussion and recommendations.

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Abbreviations and acronyms

AER	Agro–Ecological Region
AWD	Alternate wetting and drying
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
HDI	Human Development Index
IFAD	International Fund of Agriculture Development
IHDI	Inequality-adjusted Human Development Index
INMAS	Integrated management of agricultural settlements
MASL	Mahaweli Authority of Sri Lanka
MSL	Mean sea level
PIM	Participatory irrigation management
UNDP	United Nations Development Programme

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Executive summary

An increasing number of regions in the world are frequently facing water shortage, and water demand is likely to grow in the next 20–30 years due to intensified agriculture, population growth, urbanization and climate change. Future demand of water by all sectors will, thus, require as much as 25 to 40 percent of water to be re-allocated from lower to higher productivity and employment–oriented activities, particularly in water stressed regions. As such, these reallocations are likely to come from agriculture due to its high share of water use.

In view of the projected rise in water demand in agriculture and non-agricultural sectors, appropriate actions that increase water use efficiency especially in irrigation are crucial to sustainably enhance agricultural production and productivity.

In Sri Lanka, one-third of the rural population depends on agriculture. Rice is the national staple food which is cultivated twice a year on nearly one million hectares of land under a range of physical and environmental conditions. Currently, about 80 percent of paddy production comes from irrigated agriculture, while 20 percent is by rainfed area. Paddy cultivation is especially water demanding as it needs continues inundation of the field during most of the growing season. Despite being self-sufficient in paddy production, Sri Lanka has relatively low levels of water productivity and water use efficiency. Furthermore, its water and food security is extremely vulnerable to climate change.

The Food and Agriculture Organization of the United Nations (FAO) has been active to increase the understanding of the status of water use efficiency and water productivity in Sri Lanka through the project "Efficient Agricultural Water Use and Management Enhancement in Paddy Fields", funded by the Japan Ministry of Agriculture, Forestry and Fisheries (MAFF). The project objective is to identify limits and potentials of paddy rice production at national level.

This report presents a comprehensive Outlook of paddy rice cultivation in Sri Lanka which will form a basis for assisting the country to identify potential areas of improvement to achieve sustainable water resources management and food security.

The Outlook is organized in five sections:

Section 1 introduces the country profile focusing on the role of agriculture in national economy, the role of rice agriculture in national food security, trends of rice production and consumption and different rice growing environments in Sri Lanka.

Section 2 describes the surface and ground water resources of Sri Lanka and its utilization in the paddy systems and other cultural practices. It also lists and describe the typology of different types of irrigation system and its functioning. Finally, it presents the performance of irrigation system for paddy rice production in the country.

Section 3 describes the interventions carried out in the agriculture system of Sri Lanka. It mainly describes the institutional and infrastructure interventions made periodically to develop and manage water resources. The institutional setup and roles of various stakeholders are also covered in this section.

Section 4 focuses on the cross–cutting issues of climate change, social inclusiveness, gender, participation of youth in agriculture and water charges and the complexity of irrigation system and its management in Sri Lanka.

Section 5 describes the national policies and plans related to irrigation and water resources management in Sri Lanka.

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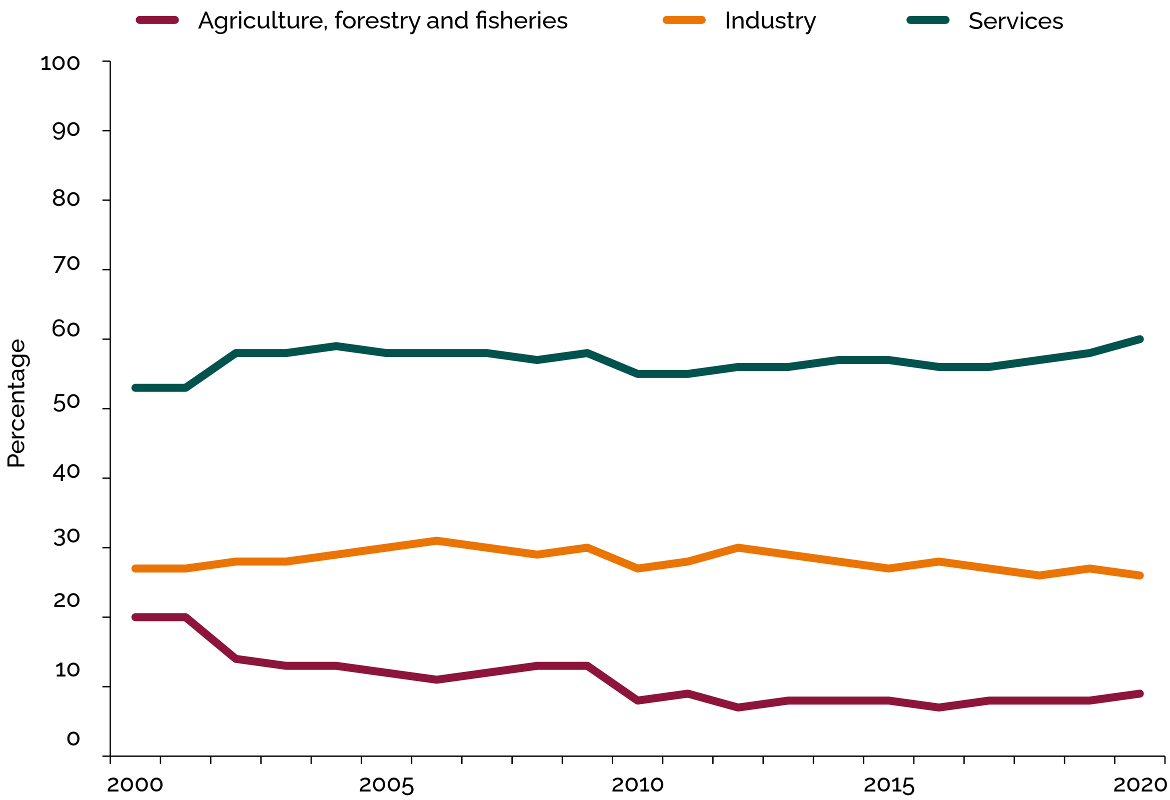
1. Country profile

1.1 ROLE OF AGRICULTURE IN NATIONAL ECONOMY

Agriculture is the backbone of Sri Lankan economy. It accounted for 25 percent of total employment in 2020 (8.1 million jobs). About 67 percent of farmers are engaged in commercially oriented production, while 33 percent produce mainly for subsistence. 65 percent of those employed in agriculture are also engaged in non-agricultural activities. Agriculture contributes 9 percent to the national gross domestic product (GDP). Industrial sector contributes 26 percent to the GDP and employs 28 percent of the labour force, while the service sector contributes 60 percent to GDP and employs 46 percent of the labour force. As the economy has gradually shifted to services and a consumption-based growth model, contribution of agriculture to the GDP has declined significantly from 20 percent in 2000 to 12 percent in 2005, 8 percent in 2010, and 9 percent in 2020 (Figure 1). The country's main crop is rice, which accounts for 40 percent of the total agricultural production, while plantation crops such as tea, rubber, coconut, sugarcane, and oil palm account for 38 percent, and fruits, vegetables, and field crops account for 22 percent.

Figure 1. Contribution of main economic sectors to the country economy



Source: World Bank. 2022. National accounts data, share of GDP and others. Washington DC, World bank Group. https://databank.worldbank.org

Sri Lanka has 2.7 million ha of agricultural land, around 1.3 million ha (48 percent) of which is classified as arable land, 1 million ha as permanent crops, and 0.44 million ha as permanent meadow and pastureland. Coconut is one of the major plantation crops, accounting for approximately 12 percent of all agricultural production. The total area under coconut cultivation is 395 000 ha, which produce 2 500 million nuts annually.

Sri Lanka is the third largest tea exporter in the world, tea exports accounted for 221 thousand tonnes of Ceylon tea (12 percent of global tea export), which brought a revenue of USD 1.15 billion and contributed 2 percent to the national GDP (CBSL, 2020). Currently, 136 582 ha are under rubber cultivation. Rubber exports stood at 7 663 tonnes in 2017, earning a revenue of USD 1 billion. Sri Lanka has historically been a global destination for the finest quality spices. Major spice exports are cinnamon, pepper, cloves, nutmeg, and cardamom, all branded under the geographical indication of Ceylon spices due to their unique aroma and flavour shaped by the climate of the country. In addition, spice manufacturing also supplies a range of essential oils and oleoresins derived from the spices. In 2018 the country ranked ninth largest spice exporter and earned USD 361 million from the export of 30 000 tonnes of spices.

Sri Lanka produces more than 900 000 tonnes of fruits and vegetables annually and exports them in fresh and processed form to several destinations around the world. About 65 percent of the fresh produce including beans, carrots, peppers and tomatoes are exported to the Middle East, the Maldives and other countries in South Asia. The country has more than 100 food and beverage manufacturers. The processed food and beverage sector covers a wide range of products, including rice, cereals, flour, bakery products, confectionery, canned food, tropical fruits, tea and oilseed. Beverages include fruit concentrates, nectars, extracts, pulp, juices and coconut milk. Exports of processed food and beverages generated USD 251 million in revenue in 2018 and provided employment for 2 million people. Ninety-eight percent of processed food items were exported to European markets. In addition, a variety of non-traditional spices and herbs are grown by smallholder farmers for export, including betel leaves, areca nuts, cocoa, and vanilla. The diverse climate that allows for the cultivating of a range of organic products as well as the availability of local resources, skilled labour, flexible operations, and compliance with international standards all contribute to making this industry sustainable and profitable in the long term. The government is also encouraging private sector participation in commercial farming and agribusinesses to develop a stronger and reliable supply base to meet the growing demand for agricultural products from Sri Lanka. Exporters continue to maintain high quality standards and ensure continuous innovation and growth in the industry to provide the best quality fruits, nuts and vegetables to the world.

Sri Lanka imports essential food items and raw materials for the animal feed industry from other countries. Food imports accounted for 7.2 percent of national expenditure and averaged USD 1.8 billion in 2018. The main imports are wheat, maize, soybean, lentils, sugar, fruit, cotton, milk and dairy products. Wheat and maize are mainly imported to maintain domestic supply in the local market, while soybean and maize are the main ingredients for the production of animal feed and concentrated feed. Raw cotton, yarn and fabric are imported for the garment industry, part of it is re-exported as finished textile goods.

1.2 RICE AGRICULTURE

1.2.1 Role of rice agriculture in food security, livelihood and economy

Rice is the staple food of Sri Lanka's 21.8 million people, and average rice consumption is about 90 kg/capita per year. Seventy-two percent of rural households (8.1 million families) cultivate rice for their livelihoods, making it the largest contributor to food security and rural economy. Large paddy fields of more than 2 ha are predominant in the country's Eastern Province, where rice cultivation is done on a commercial scale, with large–scale producers producing less than 25 percent of the total paddy. Due to land fragmentation, about 25 percent of rice production comes from smallholder farmers, who cultivate between 0.4 and 0.81 ha. A significant proportion of more than 50 percent of rice comes from farms with less than 0.4 ha area. Rice farming on small scale is economically not lucrative but it provides local jobs and food security to the smallholders. These farmers are found in the irrigated settlements in the dry zone and in isolated areas in the wet zone. Sri Lanka has several comparative advantages in the region for cultivation of paddy in irrigated areas, namely employment of family labour in smallholder agriculture, favourable weather, and fertile soil conditions. Paddy cultivation in Sri Lanka is heavily subsidised, in 2019 farmers enjoyed up to 86 percent subsidy on chemical fertilizer, subsidies also apply to other crop inputs such as seeds, irrigation water, agricultural extension services and above all a guaranteed support price of USD 0.28/kg of paddy for a certain share of the total paddy crop (Feed the future, 2021). These incentives have helped achieve self–sufficiency in rice production. However, land productivity of rice is still characterised by relatively low levels. On the other hand, the changing pattern of food consumption by different income groups indicates a faster increase in demand for food and cereals, including rice.

Rice import into Sri Lanka varies and depends mainly on rainfall during the main cropping season. The recent highest annual rice import was 300 000 tonnes in 2022 when economic challenges resulted in fertilizer shortage triggering excessive crop losses. Sri Lanka exports very small amount of rice, averaging about 6 000 tonnes/year because the agricultural sector is loosely integrated with global supply chains and even with the re-recognition of generalized system of preferences (GSP) plus status in 2017, the country's rice export is still non-competitive in high–volume markets. The paddy rice sector in the country also faces some key challenges. These include decreasing farm size due to inheritance, low mechanization, high cost of agrochemicals for rice production, low yields, shortage of labour and marketing problems. Extreme weather conditions and climate change are increasing the risks of failed harvests and household food insecurity.

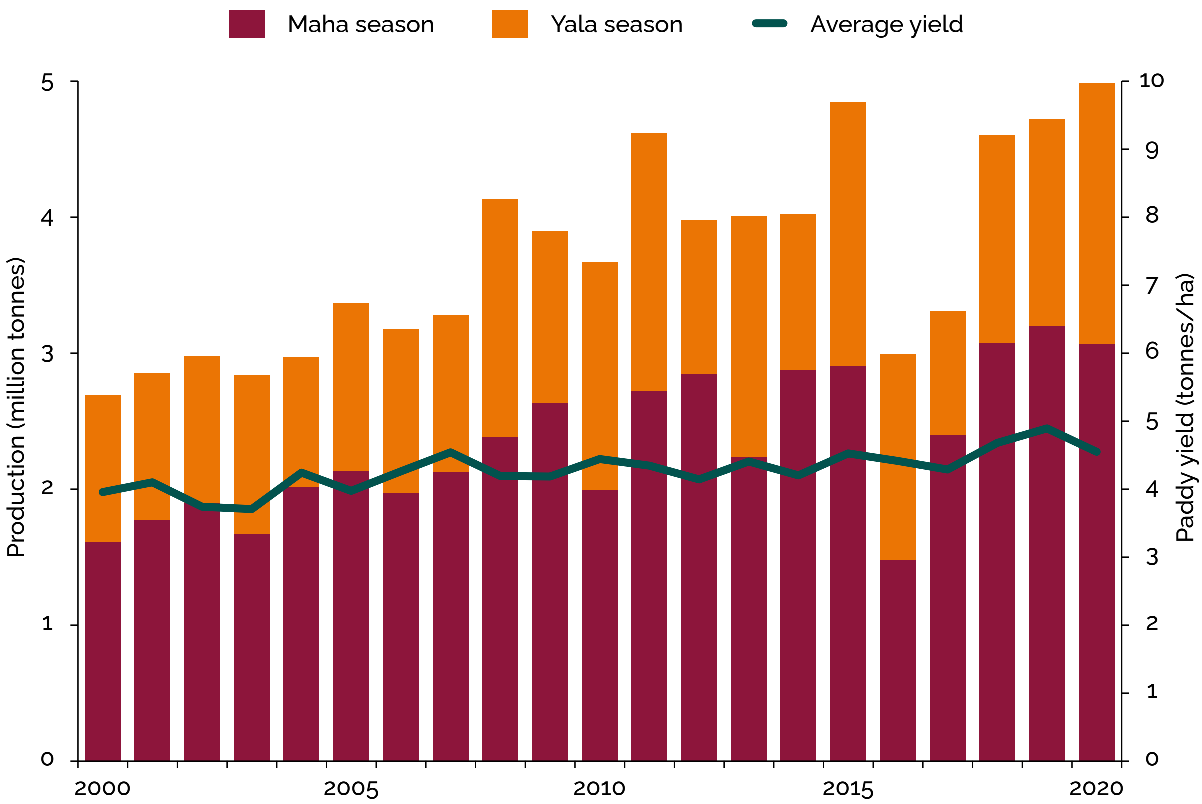
1.2.2 Rice production, consumption and typology of cultivated area

Rice is cultivated in two distinct cropping seasons throughout the country. The main cropping season is Maha, which lasts from late September to late March and is fed by the second inter-monsoon and the northeast monsoon rains. A subsequent rice crop is grown in the secondary growing season, Yala, which lasts from early April to early September and is fed by the first inter-monsoon rains and the southwest monsoon, which mainly brings rain to the southwest of the country. Sri Lanka's highest paddy production was recorded in 2020 with a total of 4.98 million tonnes, including 3 million tonnes in the Maha season and 1.98 million tonnes in the Yala season, which was 85 percent more than the production in 2000. The average paddy yield was 4.23 tonnes/ha, resulting in an average production of 3.71 million tonnes per year during the period 2000–2020. The annual paddy production for the two seasons and the corresponding yields are shown in Figure 2. During this period, the trend of paddy yield showed an increase of 32 kg/year while production was increased at 90 000 tonnes/year which is 3.3 percent increase based on the year 2000.

The current population of 21.8 million is projected to increase to 25 million by 2042 and 28.5 million by 2062. Demand for rice is expected to increase by 1.1 percent per year. Accordingly, rice production is expected to grow by 2.9 percent per year. The annual per capita consumption of rice was about 107 kg in 2019, which mainly depends on paddy production in the country and the price of imported cereal. Rice provides 45 percent calorie and 40 percent protein requirement of an average Sri Lankan.

As water is a limiting factor, the average extent of area sown in the Yala season (369 767 ha) is less than that of the Maha season (644 905 ha) with annual average of 507 336 ha (Figure 3) and cropping intensity of nearly 150 percent. Two-thirds of this area is in the dry zone where the major irrigation schemes are located. The extent of sowing and harvesting has not increased significantly over time with annual average values of 507 355 ha and 483 105 ha, respectively. More than 80 percent of landholding for paddy cultivation is less than 1 ha, with an average size of 0.35 ha. Landholding for

Figure 2. Paddy production and yield in Sri Lanka duration 2000 to 2020 period.

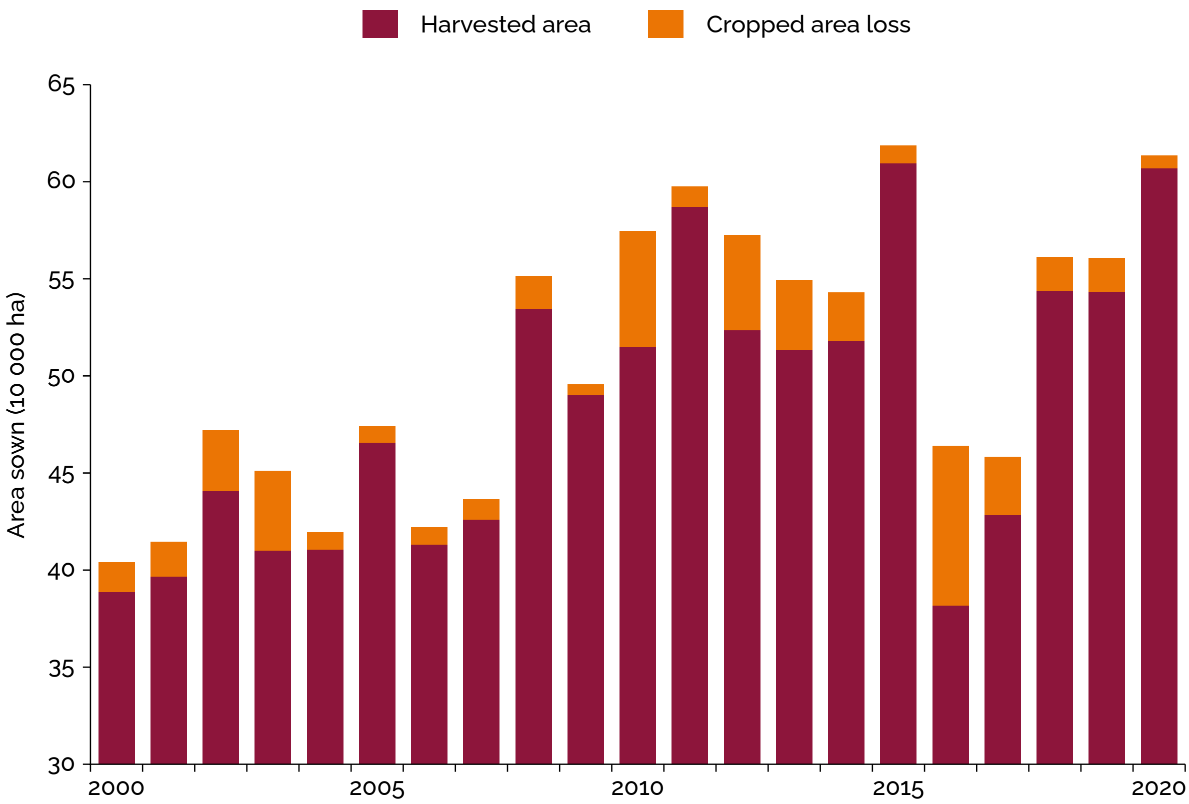


Source: Department of Census and Statistics, 2020, Agriculture statistics, Paddy statistics, Battaramulla, Government of Sri Lanka. http://www.statistics.gov.lk/Agriculture/StaticalInformation/rubpaddy

paddy cultivation ranges from less than 0.3 ha in the wet zone to 0.9 ha in the irrigated dry zone. Nearly 83 percent of the area sown in 2019–20 Maha season fell under the single owned category. Eight percent fell under the sharecropping locally called Ande and five percent under the joint ownership categories. There is a certain difference between the area sown and the area harvested due to crop failure as shown in Figure 3. This scenario is even severe in drier years and in minor irrigation and rainfed schemes.

The grain yield potential of different rice varieties is determined by crop input and its interaction with climatic, soil and biotic components of the environment. Due to these factors, rice yields and total production vary greatly in the two seasons. Gross production is also influenced by the extent of cultivated area. Farmers attributed low quality pesticides, fertilizers and seeds for lower yields. Due to the high cost of quality seeds, many farmers use indigenous and recycled seeds that are prone to pest infestation. As farmers lack the capacity to detect diseases at an early stage, entire fields could be affected by pest infestations, resulting in production losses. Proper maintenance of field drainage channels is another issue that leads to crop losses. During rainy seasons, it is difficult to drain flood water from the fields, causing them to be completely inundated. Damage from rodents, birds and, in some areas, elephants is high during the rice cultivation phase.

Figure 3. Total area sown, crop area lost and area harvested under paddy rice



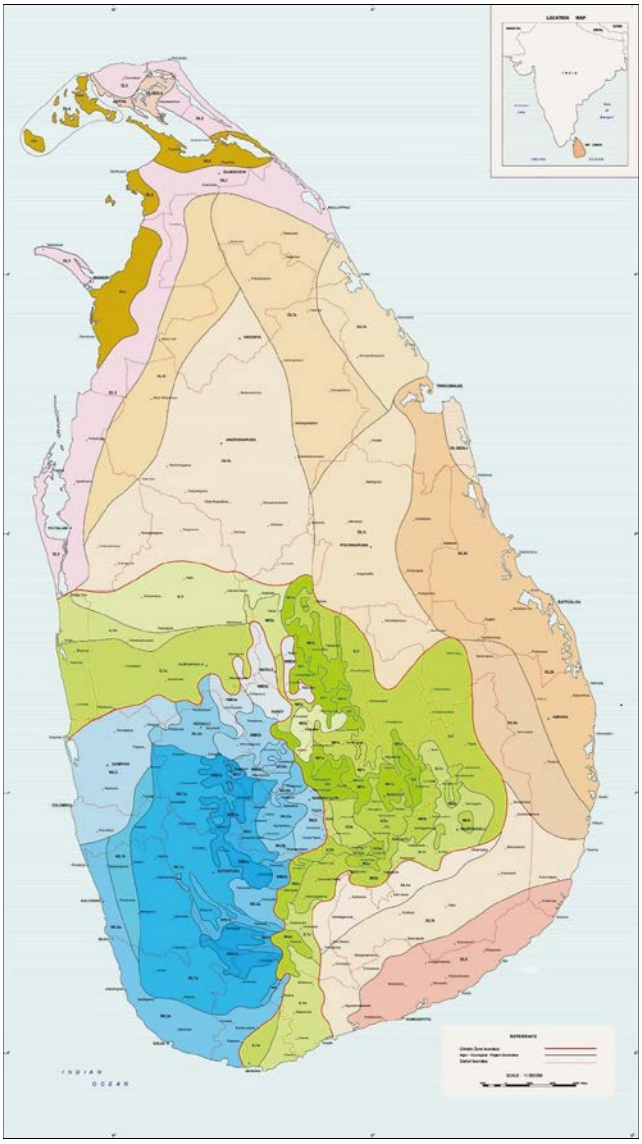
Source: Department of Census and Statistics, 2020, Agriculture statistics, Paddy statistics, Battaramulla, Government of Sri Lanka. http://www.statistics.gov.lk/Agriculture/StaticalInformation/rubpaddy

1.2.3 Rice growing environment

The country has a wide range of climatic and soil conditions. Annual rainfall ranges from 600 mm in the dry areas to 6 000 mm in the extremely humid areas. Based on the total annual rainfall, Sri Lanka is broadly classified into three climatic zones: the dry zone with rainfall below 1 750 mm, the intermediate zone with rainfall between 1 750 mm and 2 500 mm and the wet zone with rainfall above 2 500 mm. The elevation ranges from mean sea level (MSL) to 2 575 m and the average temperature ranges from 30 °C at MSL to 15 °C at the highest elevation. The country is also divided into three zones based on elevation: lowland areas are between MSL and an elevation of 300 m, 300 m to 800 m above MSL are in the midlands and all areas above 800 m above MSL are in the Highlands. Considering rainfall and altitude as well as landform and soil types, 46 major agro–ecological regions (AERs) can be identified in Sri Lanka, as shown in Figure 4 and Appendix A

Rice is grown throughout the country and is found in most agro–ecological regions (AER), except DL3 in the lowlands dry zone; IM1c, IM2a, IM3c in the midlands intermediate zone; WM1a, WM1b in the midlands wet zone; IU1, IU2, IU3a, IU3b, IU3d in the highlands intermediate zone and all regions in the highlands wet zone. In the midlands intermediate zone, only two AERs remain wet during the Yala season. Since these two AERs, namely IM2a and IM3a, are adjacent to the wet AERs such as WM1b, WL2a and WM3b, they have a relatively wet climate. All other AERs in

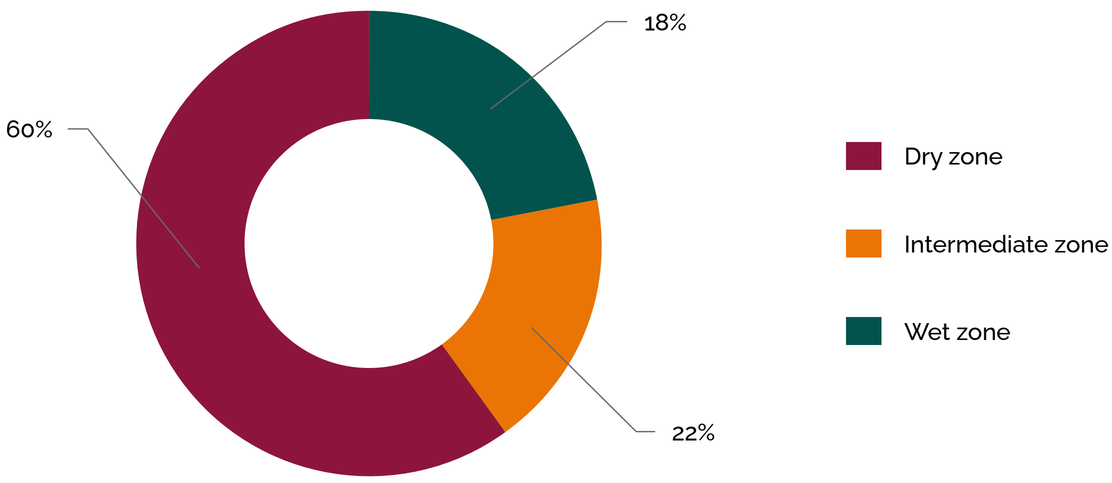
Figure 4. Major agro–ecological regions of Sri Lanka



Source: Punyawardena, B.V.R., Bandara, T.M.J., Munasinghe, M.A.K., Banda, N.J. & Pushpakumara, S.M.V. 2003. Agro-ecological regions of Sri Lanka. Natural Resource Management Centre, Department of Agriculture, Peradeniya, Sri Lanka

the intermediate zone of the midlands exhibited dry conditions during the Yala season, except for IM1a, which exhibits slightly dry condition during the Yala season. AERs IU1 and IU2 in the intermediate highlands are less likely to experience drought during the Yala season and are categorized as wet. These two AERs receive a significant amount of rainfall during the southwest monsoon, although they do not fall directly within the most effective area of the southwest monsoon. The remaining AERs of the highland intermediate zone, namely IU3a, IU3b, IU3c, IU3d and IU3e, have either slightly wet or slightly dry conditions depending on the amount of southwest monsoon rainfall in their respective regions. The percentage of rice area in the dry, medium and wet climatic zones is shown in Figure 5. Rice in the dry zone is grown under irrigated conditions because that is where most of the irrigation infrastructure is located, the challenges of growing rice in the dry and intermediate climatic zones are completely different from those in the humid zone.

Figure 5. Percentage of rice cultivation areas in the three climatic zones



Source: Department of Census and Statistics, 2020, Agriculture statistics, Paddy statistics, Battaramulla, Government of Sri Lanka. http://www.statistics.gov.lk/Agriculture/StaticalInformation/rubpaddy

There are 27 soil groups in Sri Lanka. As a single crop occupying 18 percent of the total agricultural land, rice is grown in a variety of physical environments, such as different elevations, soils and hydrological regimes. The availability of water is one of the most important factors determining the extent of rice cultivation in the country. Therefore, rice areas in Sri Lanka are categorized as either irrigated or rainfed.

Rice is grown as rainfed in the lowlands wet zone and as irrigated crop in the dry and intermediate zones. Supplementary irrigation of rice fields is provided by water collected in tanks and supplied through the diversion and distribution systems. Tank irrigation systems are differentiated according to the size of the command area. It is called a major irrigation system when the command area is more than 405 ha (1 000 ac), 81-405 ha (200-1 000 ac) is classified as medium, while less than 40 ha (200 ac) is called minor irrigation system. Major and medium irrigation systems are managed by the Department of Irrigation, while the minor irrigation systems at village tank level are managed by the Department of Agrarian Development. More than 65 percent of paddy cultivation is under the major and medium irrigation schemes, while up to 20 percent is under the minor irrigation schemes and 10 percent is rainfed. The area sown, harvested and average yield of paddy in major and minor irrigation schemes and rainfed areas during the 2019-20 season are summarized in Table 1, Table 2 and Table 3, respectively.

Table 1. Area sown (ha) of paddy in major irrigated, minor irrigated and rainfed areas

Cultivation system	Sown extent of paddy (ha)	
	2019 Yala season	2019-20 Maha season
Major irrigated	256 582 (69.6%)	349 744 (46.5%)
Minor irrigated	76 496 (20.7%)	200 204 (26.6%)
Rainfed systems	35 828 (9.7%)	200 204 (26.6%)

Source: Department of Census and Statistics, 2020, Agriculture statistics, Paddy statistics, Battaramulla, Government of Sri Lanka. http://www.statistics.gov.lk/Agriculture/StaticalInformation/rubpaddy

Table 2. Gross harvested extent (ha) in major irrigated, minor irrigated and rainfed areas

Cultivation system	Gross harvested extent of paddy (ha)	
	2019 Yala season	2019-20 Maha season
Major irrigated	249 999	342 069
Minor irrigated	68 005	198 247
Rainfed systems	28 006	199 595

Source: Department of Census and Statistics, 2020, Agriculture statistics, Paddy statistics, Battaramulla, Government of Sri Lanka. http://www.statistics.gov.lk/Agriculture/StaticalInformation/rubpaddy

Table 3. Gross harvested extent (ha) in major irrigated, minor irrigated and rainfed areas

Cultivation system	Average yield of paddy (tonnes/ha)	
	2019 Yala season	2019-20 Maha season
Major irrigated	5.2	4.9
Minor irrigated	4.3	4.4
Rainfed systems	3.1	4.1

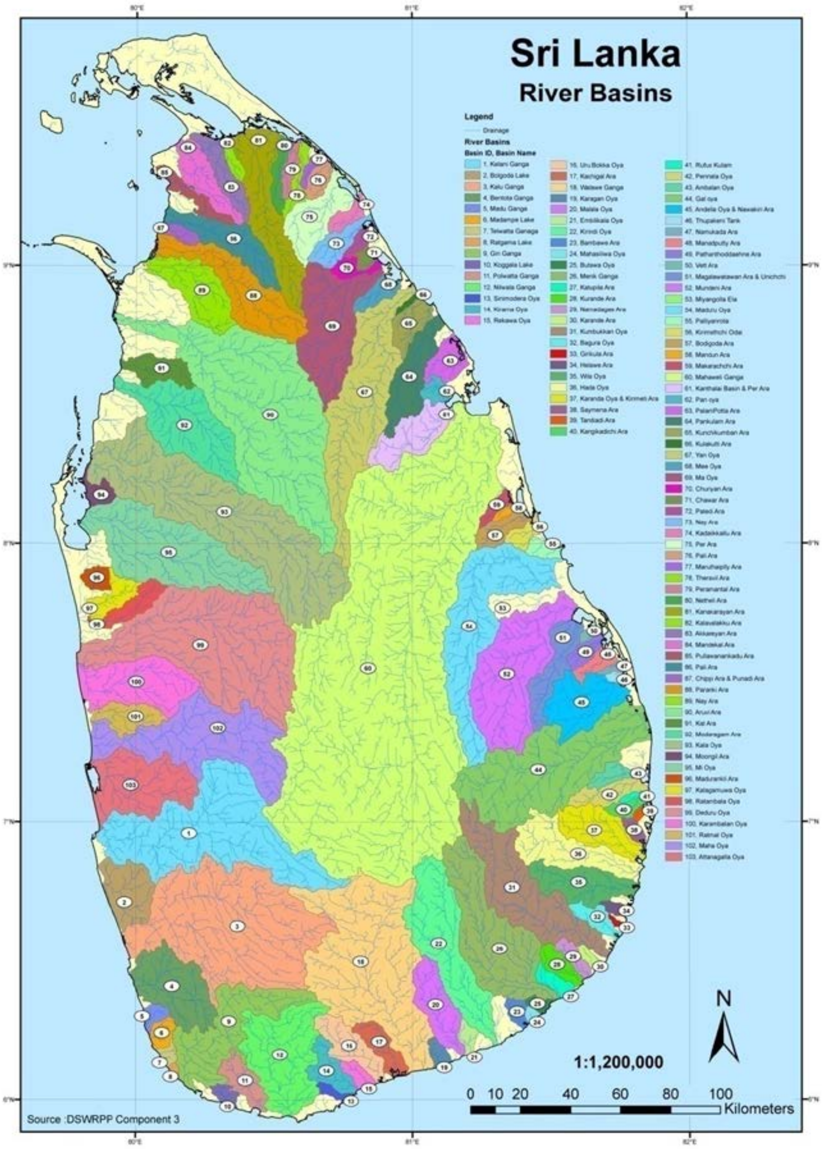
Source: Department of Census and Statistics, 2020, Agriculture statistics, Paddy statistics, Battaramulla, Government of Sri Lanka. http://www.statistics.gov.lk/Agriculture/StaticalInformation/rubpaddy

2. Water resources of Sri Lanka

2.1 SURFACE WATER RESOURCES

There are 103 rivers in Sri Lanka with a total length of about 4 500 km. The area of the river basins varies from 10 km² to over 10 000 km². Most of the river basins are small, only 17 of the 103 basins are larger than 1 000 km² (Figure 6). There are 16 major rivers with a length of more than 100 kilometres, 12 of which carry about 75 percent of the mean runoff of the entire country. The major rivers in the wet zone of the southwest monsoon are the Kelani, the Kalu, the Bentara, the Gin, the Niwala, the Maha and the Attanagalu Oya, which together carry about half of the country's runoff. The water resources of these river systems are used for irrigation development, water supply, hydropower, industrial and other economic activities. There are 26 rivers that fall in the northeast monsoon and cover a considerable spatial extent of the country. These rivers are located in dry and arid areas and irrigation, which is a priority in this zone, requires the construction and rehabilitation of reservoirs. There are two river basins that receive rainfall from two monsoon systems. In the southwestern part of the country, there are seven major river basins with catchments ranging from 620 to 2 700 km². An exception to this radial pattern is the largest catchment in the country, which is the 335 km long Mahaweli River with a catchment area of 10 448 km². Besides the Mahaweli catchment, there are four other catchments with an area of more than 2 500 km². Mean discharge data is only available for the Mahaweli catchment, which receives an annual rainfall of 28 billion m^3. The mean annual discharge of the Mahaweli is 8.8 billion m^3 and it contributes to one seventh of the total discharge of all rivers in Sri Lanka. The headwaters of the Mahaweli are located in the western part of the Central Highlands, where total annual precipitation reaches 60 000 m^3/ha. The mean annual precipitation for the lower reaches varies between 16 000 and 19 000 m^3/ha.

Figure 6. River basins in Sri Lanka



Source: Department of irrigation, 2012. River Basins of Sri Lanka through the Dam Safety and Water Resources Planning Project (DSWRPP). Colombo, Government of Sri Lanka

In addition, Sri Lanka has a network of thousands of artificial lakes and ponds, locally known as 'wewa' or 'tanks'. Some of them are particularly large and many of them are thousands of years old, while almost all of them display a high degree of sophistication in their construction and design. The network of village tanks play a vital role in supporting many important livelihood functions. With an estimated total number of more than 10 000 tanks across the country, Sri Lanka has one of the highest number of man-made water bodies. Several kilometres of canal systems and thousands of hectares of paddy fields are connected to these tanks. Storage dams distribute water through irrigation canals and streams throughout the country for agricultural purposes. In addition, the main purpose of almost all dams is to retain water for irrigation. The ancient irrigation dams and the recently constructed multipurpose dams have a total command area of 169 941 ha. Table 4 shows the command area and storage capacity of the main reservoirs. Sri Lanka's internal renewable groundwater resources are estimated at 7.8 billion m^3, almost 90 percent of the groundwater resources feed the river systems and accounted as surface water resources. With this, the total renewable water resources are estimated at 52.8 billion m^3/year.

Table 4. Districts, gross extent, dead storage and gross capacities of major reservoirs

District	Reservoir	Command area (ha)	Capacity (m^3)	Dead storage (m^3)
Ampara	Ambalan Oya	2 124.60	54 697.03	5 325.16
	Ekgal Oya	1 011.71	35 754.66	1 825.77
	Namal Oya	1 497.34	66 108.10	6 085.90
	Pallan Oya	1 416.40	141 497.20	3 423.32
	Pannalgama	1 861.56	41 992.72	3 803.69
	Rambakan Oya	1 416.40	69 227.12	3 803.69
	Rottikulama	577.89	7 759.52	-
	Senanayaka Samudraya	48 562.32	1 171 536.00	-
	Kalugaloya	607.03	12 441.10	470.14
Anuradhapura	Huruluwewa	4 208.73	83 681.13	3 423.32
	Mahakandarawa	2 468.58	55 153.48	5 781.61
	Mahawilachchiya	1 078.08	49 904.38	1 521.48
	Manankattiya	426.94	7 424.80	613.15
	Nachchaduwa	2 832.80	68 694.61	152.15
	Nuwara Wewa	1 052.18	54 849.18	1 521.48
	Padaviya	5 584.67	129 325.40	6 085.90
	Rajangana	7 211.50	124 152.40	6 846.64
	Wahalkada	809.37	65 423.43	3 080.99
	Yan Oya	-	206 672.70	12 940.14
Badulla	Ambewela	403.07	2 982.09	988.96
	Dambarawa	607.03	19 642.24	2 790.39
	Kande Ela	930.78	2 682.36	91.29
	Mapakada	607.03	11 715.36	273.87
	Nagadeepa	1 699.68	36 261.31	2 151.37
	Sorabora	809.37	25 560.79	-
	Morana	-	20 390.81	-

(continues)

Table 4. Districts, gross extent, dead storage and gross capacities of major reservoirs *(cont.)*

District	Reservoir	Command area (ha)	Capacity (m³)	Dead storage (m³)
Batticaloa	Navakiri	6 656.28	80 638.19	1 521.48
	Rugam	3 946.50	28 299.44	-
	Unnichchai	6 354.78	83 711.56	129.33
	Vakaneri	3 589.16	20 539.92	-
Hambantota	Badagiriya	667.73	13 769.35	380.37
	Kekiriobada	-	3 321.38	104.98
	Lunugamwehera	5 429.67	279 639.50	20 266.05
	Mau Ara	296.63	50 558.62	9 398.15
	Muruthawela	1 821.09	59 147.35	6 390.20
	Ridiyagama	3 438.62	39 588.79	2 434.36
	Tissawewa	1 112.89	5 349.51	76.07
	Weheragala	-	92 809.98	10 545.34
	Weerawila	934.82	17 877.33	1 977.92
	Yodawewa	1 297.83	13 160.76	418.41
Galle / Matara	Ellewela	527.71	1 293.25	-
	Kekanadura	445.15	3 514.61	-
Kandy / Matale	Dewahuwa	1 214.06	16 736.23	152.15
	Nalanda	78.91	19 560.08	-
	Wemedilla	809.37	6 989.66	435.14
Kurunegala	Ambakolawewa	339.94	10 193.88	456.44
	Attaragalla	419.25	5 611.20	-
	Batalagoda	3 089.37	7 363.94	228.22
	Deduru Oya	3 318.43	92 554.38	-
	Hakwatunawa wawa	2 577.85	30 014.15	4 594.86
	Kimbulwanaoya	991.48	10 498.18	684.66
	Mediyawa	485.62	3 948.23	-
	Magalla	2 428.12	11 380.63	106.50
	Jayawewa	819.49	11 697.10	22.82
	UsgalaSiyabalan	971.25	32 964.28	2 533.26
Moneragala	Ethimale	405.50	8 368.11	684.66
	Handapanagala	687.97	22 517.83	593.38
	Muthukandiya	809.37	37 428.29	2 738.66

(continues)

Table 4. Districts, gross extent, dead storage and gross capacities of major reservoirs *(cont.)*

District	Reservoir	Command area (ha)	Capacity (m^3)	Dead storage (m^3)
Polonnaruwa	Giritale	3 075.61	33 019.05	1 217.18
	Kaudulla	5 463.26	158 233.40	6 846.64
	Minneriya	9 095.32	167 362.30	6 085.90
	Parakrama Samudraya	10 193.23	176 643.20	22 822.13
Puttalam	Inginimitiya	2 642.60	89 512.95	6 466.27
	Tabbowa	887.07	23 430.72	289.08
Trincomalee	Kantale	7 510.97	173 448.10	-
	MahadivulWewa	562.51	27 797.35	1 217.18
	Mora Wewa	1 635.34	52 871.26	2 586.51
	Vendrasan	708.20	30 794.65	-
	Wan Ela	588.82	3 516.13	83.68
Vavuniya / Mannar	Pavatkulam	1 673.38	41 079.83	760.74
	Akathimuruppu	2 521.60	11 599.73	-
	Giants Tank	9 889.72	47 926.47	266.26
	Viyathikulam	494.93	2 738.66	-

Source: Department of irrigation, 2020. Irrigation regions of Sri Lanka, scheme list. Colombo, Government of Sri Lanka. https://www.irrigation.gov.lk

Between 1950 and 1970, the activities of the Irrigation Department were focused on the restoration and rehabilitation of the major reservoirs such as Kantale, HuruluWewa, Padawiya, Kaudulla and the construction of new reservoirs such as Rajangana and Wahalkada. The total capacity of the reservoirs, including the multipurpose dams built for irrigation and hydropower, is 7.93 billion m^3. These dams supply water to about 80 percent irrigated paddy fields and generate 35 percent of the energy demand through hydropower.

The National Water Supply and Drainage Board (NWSDB) water supply systems cover 31 percent of piped water supply, while 8-9 percent is managed by local authorities. Small communities have their own water supply systems managed by community-based organizations (CBOs). Despite this, providing safe and adequate amount of drinking water to the whole nation remains a challenge.

2.1.1 Multi-functionality of the tank water

The water from the tanks is mainly used for irrigating rice in the Maha season, while a number of other crops are occasionally irrigated in the Yala season, depending on water availability. Home gardening and fishing are also important components of the farming system which depends on these tanks. Other secondary uses of tank water include bathing, livestock rearing and domestic purposes. Inland fishing as a commercial activity began in 1952 with the introduction of exotic species and is now recognized as an important contributor to the agricultural sector. In the 1980s, shrimp farming began in coastal ponds and has since developed into a profitable business that contributes significantly to the national economy. Sri Lanka has traditionally relied on fish as an important element of animal protein supply, with per capita fish consumption estimated at 31 kg/year. This sector also provides many jobs, not only in fishing, but also in processing, distribution and trading, as well as boat building and maintenance. Inland fishery production in 2017 was about 81 900 tonnes, mainly from water bodies designed to supply water to the local population and agriculture. Freshwater finfish aquaculture, mainly carp and tilapia, accounted for 82 percent of total aquaculture production, while marine shrimp accounted for 16 percent.

Most of the village tanks in the dry zone are set up in a cascade system. In such systems, the tanks are interconnected so that the overflow and used paddy water 'Vel Pahu Wathura' of the upper tank is reused as source water for the lower tanks. The quality of this water is acceptable for agricultural needs, but the intensive use of agrochemicals that has emerged in the last two decades is causing water quality problems, not only in cascade systems but almost in all water bodies. A downstream tank of a cascade system stores the water from its own catchment and the overflow and drainage that comes from the upstream tank and its command area, which cause deposition of hazardous substances in the downstream tank. Originally these village tanks are characterized by special conditions that help improve water quality in a cascade system. Godawala, for example, has a natural settling pond upstream of the main tank which helps to trap excess sediments and allow the relatively clean water to flow into the main tank, while Kattakaduwa has a strip of marshland just downstream of the tank where aquatic plants and reeds grow to absorb the salinity of overflow water before it is intercepted and used into the downstream rice fields. Almost all cascade systems with pollution problems have been identified by the Department of Agrarian Development and a number of them have been rehabilitated to provide good quality water.

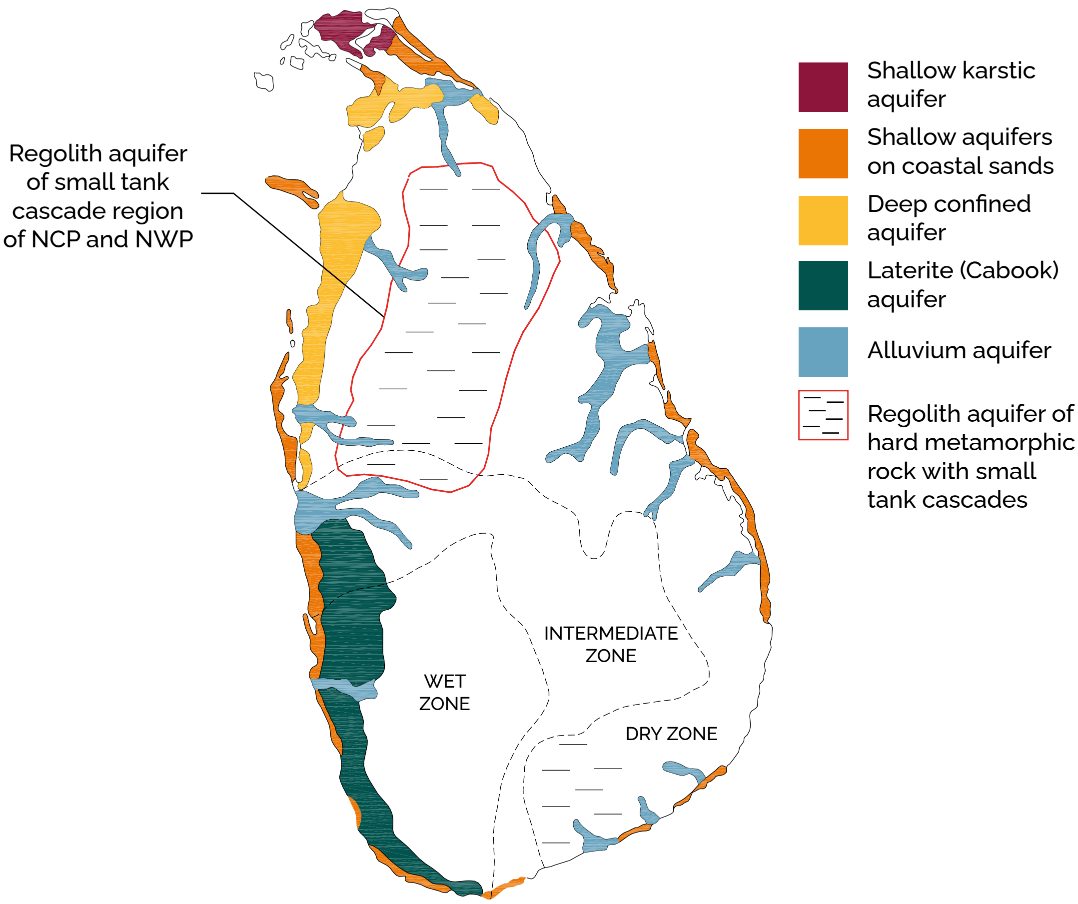
2.2 GROUNDWATER RESOURCES AND AQUIFERS

In Sri Lanka, groundwater resources for irrigation receive less attention than the surface water resources. The available groundwater potential is extensively used for domestic use, small-scale irrigation, industry and other purposes. Groundwater covers about 80 percent of domestic water needs. This demand is steadily increasing with the rising population. In recent years both shallow and deep aquifers have been over-exploited due to high demands for irrigation and domestic supply. As a result, it is increasingly common for domestic wells to dry up during dry season. There are six main types of aquifers that have been delineated and identified in the country: 1) karst, 2) coastal sand, 3) deeply confined, 4) laterite (cabook), 5) alluvium, and 6) shallow regolith in the hard rock region. In addition to these main aquifers, there are a large number of smaller aquifers throughout the country.

The entire Jaffna Peninsula is underlined by Miocene limestone formations, which are generally 100 to 150 m thick and heavily karstified. There are several distinct and confined aquifers in the sedimentary, limestone and sandstone formations of the northwestern and northern coastal plains. The groundwater reservoirs are more than 60 m deep and have relatively high recharge rates. The deeper and larger alluvial aquifers are located along the lower reaches of the major rivers that cut through the various coastal plains surrounding the lowland regions of the country. Rivers such as the Mahaweli Ganga, the Kelani Ganga, the Deduru Oya, the Mi Oya, the Kirindi

Oya and the Malwathu Oya have broad and deep alluvial beds of varying texture and gravel content in their lower reaches. Old buried river beds with high groundwater yields are found in the lower reaches of the Kelani River. The alluvial formations of these larger rivers vary in thickness from 10 to 35 m and extend for several hundred metres on both sides of the river beds. Groundwater in the hard rock region is found in the weathered rock zone, the regolith, and in the deeper fracture zone of the bedrock. The weathered zone is generally between 2 and 10 m thick, while the fracture zone is 30-40 m deep. The laterite formations in southwestern Sri Lanka known as "Cabook" have considerable water storage capacity, which depends on the depth of the Cabook formation. The aquifer in this vesicular laterite responds very quickly to the first rains after the usual dry season in February-March and then continues to fill up with the monsoon rains.

Figure 7. Different types of aquifers in Sri Lanka



Source: Panabokke, C.R. & Perera, A.P.G.R.L. 2005. Groundwater resources of Sri Lanka. Water Resources Board, Colombo, Sri Lanka.

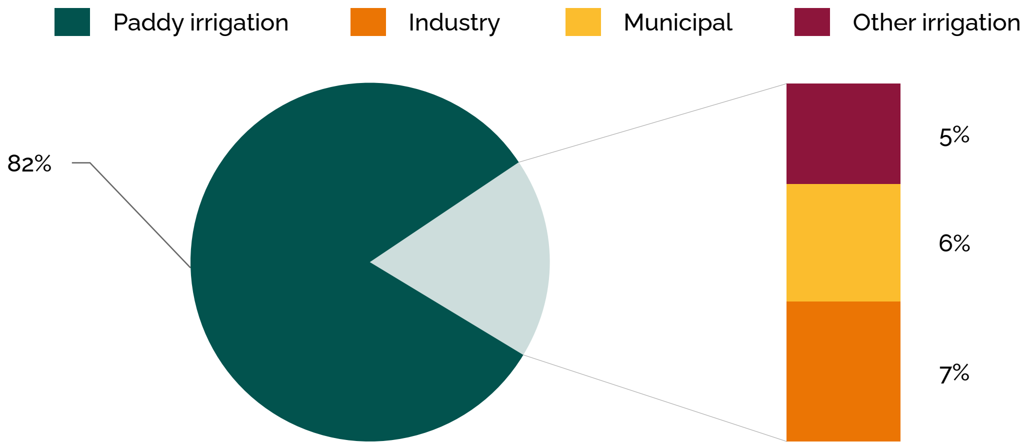
2.3 WATER USE IN PADDIES

More than 10 000 tanks, 379 irrigation schemes under the Irrigation Department, the Mahaweli Authority and Provincial Water Councils are the main components of the irrigation system with a total irrigated area of about 798 000 ha. Of this, 565 000 ha (54.3 percent) falls under major irrigation schemes and 233 000 ha (22.3 percent) under minor irrigation schemes, while a non-irrigable area of 243 000 ha (23.3 percent) is rainfed. The total water withdrawal is estimated at 12.95 billion m^3, with about 10.63 billion m^3 of the total withdrawal used only for paddy irrigation.

The remaining 0.68 billion m^3 is for irrigation of other crops, 0.81 billion m^3 for municipal use and 0.83 billion m^3 for industry. Figure 8 shows the percent share of water use by these sectors. Of the total abstraction, 76 percent is allocated to the eastern, north-western and north-central provinces and to Hambantota district in the southern province.

Farmers use groundwater for paddy irrigation to supplement surface water in the dry zone. The number of agricultural wells has considerably increased in recent decades. It is estimated that there are more than 50 000 wells for irrigation in the dry zone. The number of irrigation pumps is estimated at about 100 000, including those used to pump water from rivers, irrigation canals and tanks. The increase in the construction of agricultural wells is partly due to the government subsidy for masonry and concrete lined wells introduced in 1989. In addition, the water table is very shallow in some areas, which reduces the cost of digging shallow wells and drilling tube wells. The use of solar tube wells in agriculture, although on the rise worldwide, is not commonly practiced by farmers in Sri Lanka.

Figure 8. Total water withdrawal and its distribution among different sectors



Source: Department of irrigation. 2018. Administration Report. Colombo, Governmentof Sri Lanka. Cited 26 March 2021. www.irrigation.gov.lk

2.4 WATER REQUIREMENT OF PADDY CROP

Paddy requires more water than any other food crop. Apart from its critical functions in plant physiology, water plays an important role in carrying out various management practices in rice cultivation, such as crop establishment, transplanting, weeding, fertilizer application and pest and disease control. Water requirements for rice cultivation can be divided into different phases of crop production (Table 5).

In Sri Lanka, the water requirement of paddy also depends on the agro–ecological region, the maturity period of the rice variety and the growing season of the rice variety. The water requirement of paddy is higher in 4-month varieties than in 3-month varieties and higher in the dry zone than in the wet zone (Table 6). The average water requirement for paddy cultivation is estimated at 1 200-1 800 mm (3 000-5 000 litres/kg of paddy), depending on agro–climatic conditions, crop variety, water use efficiency and soil characteristics.

Table 5. Water requirement for paddy production

Crop growth stage	Water requirement (mm)	Water requirement (%)
Nursery	40	3
Main field preparation	200	16
Transplanting to panicle initiation	460	37
Panicle initiation to flowering	417	34
Flowering to maturity	123	10
Total	1 240	100

Source: Expert Rice System, 2015. Water requirement of paddy production in Sri Lanka, Hyderabad, Indian Institute of Rice Research. http://www.riceexpert.in

Table 6. Water requirement of paddy grown in different agro–ecological regions

Agroecological region	Water requirement (mm)					
	4 months		3 1/2 months		3 months	
	Yala	Maha	Yala	Maha	Yala	Maha
Dry	1 550	1 350	1 475	1 325	1 425	1 275
Intermediate	1 425	1 325	1 375	1 300	1 325	1 250
Wet	1 350	1 325	1 300	1 275	1 275	1 250

Source: Rice Research and Development Institute, 2020. Publications, Water Management & GIS Division, Peradeniya, Department of Agriculture, Government of Sri Lanka.

2.5 WATER REQUIREMENT FOR OTHER MANAGEMENT PRACTICES

2.5.1 Weed management

The success of rice weed control often depends on better water management. The emergence, composition and distribution of weeds in rice fields is regulated by the depth and duration of water levels. The optimum soil moisture for weed seed germination is below saturated conditions; therefore, they are very sensitive to soil moisture and standing water. Increasing soil moisture above saturation levels progressively reduces weed germination, and maintaining 25-50 mm of standing water can prevent more than 90 percent of potential weed growth. Conversely, intermittent wetting and drying of the soil provides ideal conditions for pervasive weed growth. Maintaining standing water height at the beginning of crop establishment is an effective way to reduce the weed population. This is more feasible in transplanted rice where the seedlings are already tall and competition with weeds can be completely eliminated after sowing. However, with direct seeded rice, standing water can only be maintained when the seedlings are at least 7-8 days old. Direct seeded crop requires more water but less labour and tend to mature faster than transplanted crop. By using this method, the plants are not subjected to stresses such as being pulled out of the soil and re-establishing fine roots in the puddle, but they experience greater competition from weeds. About 95 percent of the rice grown in Sri Lanka is direct-seeded (intermittent wetting and drying). The average paddy yield in the irrigated zone is about 5.0 tonnes/ha and in the rainfed zone about 3.3 tonnes/ha.

2.5.2 Fertilizer management

Water and fertilizer are important components of high quality and high yielding rice cultivation techniques. Water and nitrogen have a coupling effect on rice yield formation and nitrogen use efficiency. Number of panicles and grains per panicle increase significantly with intermittent irrigation and nitrogen fertilizer application. Nitrogenous fertilizer is a water soluble compound which has high application efficiency when applied through irrigation. However, this method is not commonly practiced in rice cultivation in the country.

2.5.3 Plant disease control

Moisture on foliage or standing water in the field can cause the development of fungal and bacterial diseases, as spore germination requires a thin film of moisture on the plant surface. High relative humidity maintains leaf wetness through condensation, and paddy cultivation provides an ideal situation for this. Fields flooded with storm water can cause outbreak of bacterial blight, bacterial leaf streak and sheath blight epidemics. Controlled irrigation and effective drainage of paddy fields especially after heavy rains, can help control the accumulation of excess water, which in turn facilitates the control of these diseases.

2.6 IRRIGATION AND WATER MANAGEMENT IN PADDY FIELDS

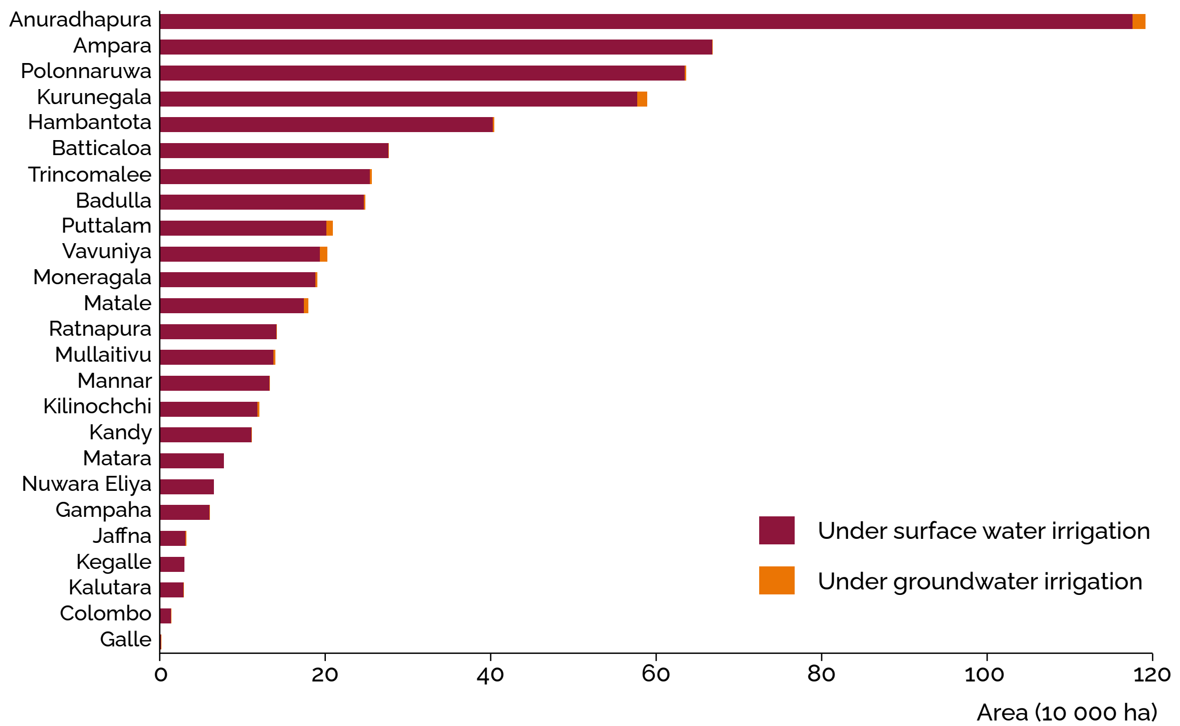
2.6.1 Irrigation potential and development

Sri Lanka has an irrigation potential of about 798 000 ha as of 2018, of which the Mahaweli project alone has an irrigated area of 365 000 ha. The Mahaweli Development Project started in 1964 with the technical support of the UNDP and FAO, which aimed to develop the largest water resources and irrigated agriculture programme in the country. Traditionally, irrigation was developed mainly for rice cultivation. About 73 major, 160 medium and more than 12 000 minor irrigation reservoirs (village tanks) and several canals are the main components of the overall irrigation system. Between 1980 and 1995, the irrigated area increased from 457 200 to 570 000 ha, after which little expansion of irrigated area was observed and since 2011, Sri Lanka has reached the full potential of irrigation expansion. Two-thirds of the irrigated area is in the dry zone, while one-third of the area under controlled irrigation is in the wet zone.

2.6.2 Major irrigation system for paddy fields

Paddy is grown in Sri Lanka under three types of irrigation systems: i) major and medium irrigation systems, ii) minor irrigation systems, and iii) rainfed paddy cultivation. Irrigation systems with cultivated area of more than 405 ha (1 000 ac) are classified as major, 81–405 ha (200–1 000 ac) as medium and less than 40 ha (200 ac) as minor irrigation systems. Most irrigation systems in the dry zone are fed by storage and flood control reservoirs. Excess runoff during the rainy season is impounded by building a dam across the valley, irrigation water is released to the command area during the dry season to meet crop water requirements. In wet zones where the topography is relatively steep, diversion weirs, also called anicut, are built across perennial streams to divert water into open canals. These canals deliver irrigation water by gravity to command areas. Conversely, in wet zones with relatively flat topography, paddy fields are constructed with drainage channels that drain excess water from the fields to improve aerobic decomposition and reduce pest infestations that might occur in standing water. Lift irrigation is used to irrigate high lands by pumping water from streams, reservoirs, canals and tube wells. In Sri Lanka, more than 45 percent of the rice area in the dry zone is irrigated by major and medium irrigation systems, contributing to more than 65 percent of rice production, followed by 25 percent area under minor irrigation systems, accounting for 20 percent of rice production. Rainfed farming systems cover 30 percent area and produce 10 percent of rice due to its low productivity. The largest irrigated areas are in Anuradhapure, Ampara, Pollonnaruwa, Kurunegala, Hambantota and Batticaloa districts (Figure 9). The availability of water and irrigation potential are the main factors determining the expansion of irrigated land. FAO estimates show that the extent of irrigated area has remained constant since 2011, as Sri Lanka has fully utilized its irrigation potential. However, water scarcity can be addressed and the extent of harvested area could be maintained at the maximum level by adopting best practices in rice farming.

Figure 9. Irrigated areas in paddy cultivation districts



Source: FAO. 2022. FAO Aquastat. Global Information System on Water and Agriculture. Available at: https://www.fao.org/aquastat/en/geospatial-information/global-maps-irrigated-areas/irrigation-by-country/country/LKA

2.6.3 Water management in major irrigation schemes

Water management in irrigation systems is an integrated process of storing, diverting, conveying, regulating, measuring, distributing and applying the right amount of water at the right place and time, and removing excess water from farms to increase production in conjunction with improved cultural practices. The divisional irrigation engineers, regional directors of irrigation, and water management division help in accomplishing these tasks. The Irrigation Department also performs pre-seasonal and seasonal planning, conducting planning meetings, scheduling, reviewing, correcting and coordinating water allocations in the major and medium irrigation schemes including the Mahaweli project, operating and monitoring the major and medium reservoirs and general performance evaluation of irrigation system. Table 7 shows the important components of the irrigation system under the umbrella of Irrigation Department. The Water Management Division is responsible for directing and coordinating irrigation and water management activities in all schemes under the supervision of the Irrigation Department and Department of Agrarian Development, seasonal cultivation planning is done in accordance with the rules and regulations outlined in the statutory enactments as well as regional practices.

Table 7. Components of irrigation system under the umbrella of the Irrigation Department

Major reservoirs	73 (command area more than 405 ha)
Medium reservoirs	171 (command area between 81-405 ha)
Total capacity of reservoirs	3 940 million m^3
Anicuts	113
Lift irrigation	5
Drainage schemes	19
Total No of structures	381
Total extent	304 953 ha

Source: Department of irrigation, 2020. Major and medium irrigation schemes. Colombo, Ministry of irrigation, Government of Sri Lanka. http://www.irrigationmin.gov.lk/major-and-medium-irrigation-schemes/index.php

2.6.4 Water management in minor irrigation schemes

The Agrarian Development Act No. 40, amended in 2011 by Act No. 46, defines a minor irrigation scheme as one that irrigates up to 80 ha of agricultural land. There are 48 050 minor irrigation schemes in Sri Lanka (Table 8). Water management in minor irrigation schemes is based on different types of delivery mechanisms, which are under the umbrella of the Department of Agrarian Development. These are:

Continuous delivery: Water is diverted from field canals to the paddy fields whenever the farmer deems it necessary. This method is practiced only in the wet zone where rainfall is abundant and field channels are always full of water.

Rotational delivery: Water is distributed to users according to an agreed and approved rotational

Table 8. Minor irrigation schemes under the umbrella of the Department of Agrarian Development

	No. of minor irrigation schemes	Command area (ha)	No. of farmer families benefited
Minor tanks	15 958	190 516	386 860
Anicuts	15 807	96 813	294 030
Canals	16 285	64 015	177 238
Total	48 050	351 344	858 128

Source: Department of Agrarian Development, 2018. Annual report 2018. Colombo. Ministry of agriculture, Government of Sri Lanka.

schedule. Irrigation water is supplied from the village tank to the main canals and then to the distribution and field canals. The flow in the canals is regulated by sluices and the main and distribution canals always flow at full capacity. Water is supplied to farmers sequentially either from the distribution canals or from the field canals through field gates, the time, duration and flow rate of water is determined by the size of land holding of each farmer. This method eliminates the travel time from the water tank to the field turnout, as the canals are always flowing full. This method ensures equitable distribution of irrigation water among users and strengthens the unity of paddy farmers.

Intermittent delivery: This method is applied to small tank irrigation schemes in the dry and intermediate zones. The tank sluice is closed after delivering water to a group of farmers for a certain period of time. The sluice can be opened for the next delivery when another group of farmers raises a demand for water. This method helps to conserve water in the tank and future deliveries can be adjusted or postponed based on the rainfall received.

Demand-based delivery: This method is useful when water is very scarce. The water delivery is set from time to time based on the water demand of the plants and the rainfall received. This method requires testing the moisture content of the paddy fields for irrigation.

2.6.5 Equity of water distribution

Irrigation water should be provided in sufficient quantity at the right time and place to ensure equitable distribution of water. Therefore, the system should be able to maintain the required flow rate up to the end of the distribution channel. The main causes of inequitable water distribution are the dilapidated canals due to inadequate maintenance, inefficiencies in the system, inadequate water supply and sequential water delivery. In an inequitable water distribution system, upstream farmers receive more water while downstream users suffer from water shortages, which increases the incidents of conflicts between water users.

2.6.6 Groundwater irrigation

Sri Lanka has groundwater resources of 7.8 billion m^3, 90 percent of which is discharged into rivers and streams and accounted for as surface water. Groundwater irrigation is not common, it is largely driven by the commercial needs and is mainly used for irrigation of high–value food crops and vegetables. Less than 30 percent of total irrigation needs are met by groundwater, but paddy fields are rarely irrigated with it. There are three types of groundwater wells in Sri Lanka: i) lined dug wells, ii) unlined dug wells and iii) tube wells. These wells are used to pump shallow groundwater and are between 4 and 12 m deep, with well diameters varying between 4 and 6 m. Tube wells are relatively deeper than dug wells and usually sink to a depth of more than 18 m. Groundwater from all three types of wells is pumped using pumps powered by diesel engines. A single well can irrigate up to 0.2 to 0.8 ha in a day, which is suitable for individual farmers. Groundwater for irrigation is freely available to farmers in Sri Lanka and there are no water charges except for pumping costs.

The government and various non-governmental organizations provide investment and subsidies for the construction of dug wells to increase the availability of water for irrigation during the dry season. On the other hand, the lack of a formal groundwater management policy in Sri Lanka has resulted in deteriorating groundwater quality, and farmers in several areas have abandoned their dug wells not because of drying up but because of poor water quality. The groundwater level in the wells fluctuates due to the water level in the surface reservoirs, as the aquifers are hydrologically connected to the river systems. Overall, there is a decreasing trend in groundwater levels in the dry zone as the density of agricultural wells increases. The density of agricultural wells varies considerably between regions and systems within a region, but in general, well density is higher in the dry zone and in the catchments of Malwathu Oya, Daduru Oya, Mee Oya and Yan Oya. Data related to groundwater use in irrigation is particularly poor in Sri Lanka and even basic information on the number of agricultural wells is missing. Efforts are required to support groundwater data collection and improve consistency, reliability and coverage of available information.

2.7 WATER USE EFFICIENCY

Water use efficiency is the ratio between the amount of water used to effectively irrigate crops and the amount of water diverted in to the irrigation system. In an irrigation system, inefficiencies arise from the amount of water that does not reach the root zone of the crops and is lost: as evaporation from reservoirs and canals; as seepage, leakage and overflow from deteriorating canals; and as non-beneficial use by weeds and shrubs in the field. Water used for crop irrigation includes green water (effective rainfall) and blue water (irrigation water from surface and groundwater sources). Water use efficiency in paddy cultivation is higher when the green water is used to the maximum and the blue water is conserve for other productive uses. Irrigated agriculture is the largest consumer of water resources in Sri Lanka, but the performance of this sector in terms of water use efficiency is not impressive in terms of water use efficiency.

Inadequate allocation of funds for repair and maintenance, low standard of irrigation technology, lack of agricultural water management, improper operation of systems and uncoordinated approach to rehabilitation and maintenance of irrigation infrastructure are some of the major reasons for low water use efficiency. Several interventions in the irrigation sector such as the Mahaweli Development Project and Participatory Irrigation Management (PIM) have been implemented with the aim of improving the performance of irrigated agriculture, but the overall irrigation efficiency in the country remains at 30 percent, which is far below its potential.

It is estimated that increasing the overall irrigation efficiency to a level of 55 percent could lead to a 35 percent reduction in water demand, equivalent to more than 3.9 billion m^3 of blue water. The major irrigated areas have the potential to contribute to a 78 percent reduction in demand if water use efficiency is increased to the potential levels. Much of the blue water is lost during the irrigation application, flood irrigation, which is common in Sri Lanka, is a low–efficiency method of water use in the fields. Sequential flooding of irrigation basins in a field results in significant water wastage compared to direct application of water to each basin. Farmers prefer sequential flooding as this method is less labour intensive and it facilitates mechanized field operations by reducing the number of field channels for direct application of water. Improper levelling of fields and failure to take into account topographic elevations and slopes of fields also cause significant water loss from fields.

The problems identified and the estimated increase in irrigation efficiency show that if the currently developed water resources are used efficiently, only a portion of these water savings will be sufficient to meet future irrigation needs. In addition, the lack of an adequate water monitoring network and reliance on manual estimates result in excessive over-allocation and misuse of water; in the Maha and Yala seasons, for example, this could amount to 63 and 52 percent respectively. Adjusting water allocation plans to take into account the contribution of green water could lead to a further reduction of blue water allocation; in the Maha and Yala seasons, this could be by 35 and 8 percent respectively. Effective Tariffs collection could be introduced with the aim of reducing water consumption and improving water use efficiency. However, the decision of tariff introduction and its impact on water use efficiency could be based on comprehensive socioeconomic and technical studies in pilot projects.

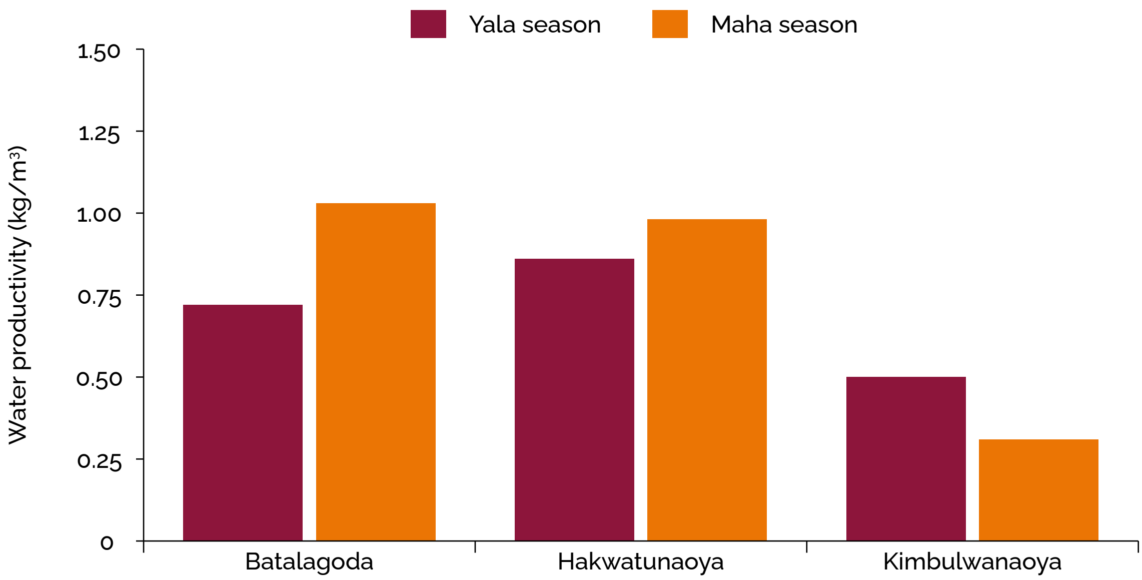
2.8 WATER PRODUCTIVITY

Water productivity per crop is termed as Crop Water Productivity (CWP), and it is defined as the agricultural production per unit volume of water. CWP can be influenced by several external factors since agriculture production is the result of selected crop variety, cropping season and crop management practices.

The water productivity of lowland rice in Sri Lanka varies between 0.2 and 1.2 kg/ m^3, well below that of wheat (0.8 to 1.6 kg/ m^3) and maize (1.6 to 3.9 kg/ m^3). Rice cultivation is a water–intensive activity, consuming up to 3 000–5 000 liters to produce one kilogram of rice. The average water consumption for rice cultivation in Sri Lanka is estimated at 1 200–1 800 mm, almost double that of other rice growing countries. This is due to frequent irrigation, un-levelled fields, high soil permeability and continues flooding of rice fields. Figure 10 shows a comparison of the water productivity of three major irrigation schemes, namely Batalagoda, Hakwatunaoya and Kimbulwanaoya in the upper catchment of the Deduruoya.

The higher water productivity in Batalagoda and Hakwatunaoya during the Maha season is due to higher paddy production achieved through optimal irrigation and other inputs such as nitrogen fertilizer and better crop management practices. The higher water productivity is also reflected by the higher unit production value of irrigation water provided during the Maha season, which is about USD 0.079/m^3. This shows that optimal nitrogen management is as important as water

Figure 10. Water productivity of paddy rice in three major irrigation systems in 2012-13



Source: Lakmali, W. A. S., Gunawardena, E. R. N., & Dayawansa, N. D. K. (2015). Comparative performance assessment of major irrigation systems in Upper Deduru Oya Basin. Tropical Agricultural Research Vol. 26 (2): 343 – 354

management to increase water productivity of rice through higher grain number and biomass yield. In Kimbulwanaoya, farmers irrigated rice fields with sequential flooding, which resulted in excessive water use and comparatively low water productivity, especially in Maha season.

Water productivity of rice can be improved by reducing large amounts of unproductive water outflows during crop growth and using green water more efficiently. Instead of constantly flooding the rice field with 5–10 cm of water, the depth of flooding can be reduced in levelled fields, the soil can be kept near saturation or alternate wetting and drying (AWD) regimes can be introduced. Dry–seeded rice farming technology offers a significant opportunity to save irrigation water through more effective use of green water. The AWD could reduce irrigation requirements by up to 20 percent compared to the current practice of continuous flooding of paddy fields. With AWD, two to five number of irrigations can be reduced without reducing yield. Evapotranspiration and seepage from paddy fields have not been adequately studied in various rice growing areas in Sri Lanka. These parameters should be considered in water management, which will ultimately lead to sustainable rice production system in Sri Lanka.

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3. Major interventions and institutional management of agriculture systems

3.1 IRRIGATION DEVELOPMENT

3.1.1 Development of Mahaweli irrigation systems

The Mahaweli Development Project, conceived in 1961, is one of the long-term water resources development programmes in Sri Lanka. The project has several objectives related to water resources infrastructure development, hydropower generation, flood control, irrigation development and facilitating settlement of landless families in the Mahaweli Basin. The Mahaweli Authority, Sri Lanka (MASL) is currently operating several water resource, social development and irrigation projects such as System B, C, D, G, H, L, Huruluwewa (HU), Rambakanoya (RO), Victoria (VT) and Udawalawa (UW) in the 24 districts of Sri Lanka. These projects were developed under the accelerated Mahaweli Development Programme (Table 9). The total water storage capacity of the main reservoirs in Mahaweli is about 3 157 million m^3. In addition to the main reservoirs,

Table 9. Irrigation systems identified in the accelerated Mahaweli development programme

System	No. of districts	No of divisional secretariats	Name of district
B	2	3	Polonnaruwa Batticaloa
C	3	3	Ampara Badulla Polonnaruwa
D	2	2	Trincomalee Polonnaruwa
G	2	2	Polonnaruwa Matale
H	2	10	Anuradhapura Kurunegala
L	3	3	Mullaitivu Anuradhapura Vavuniya
Huruluwewa (HU)	2	6	Anuradhapura Matale
Udawalawa (UW)	3	7	Ratnapura Hambantota Monaragala
Victoria (VT)	3	7	Kandy Nuwara Eliya Matale
Rambakenoya (RO)	2	3	Ampara Badulla

Source: Asian Development Bank, 2015. Mahaweli water security investment programme, Water balance assessment, June 2015, ADB. https://www.adb.org/sites/default/files/linked-documents/47381-001-sd-04.pdf

19 medium sized reservoirs and 524 small tanks are maintained and operated by MASL. The main reservoirs are built to control floods, generate hydropower and supply water to irrigation schemes. The total length of irrigation canals in Mahaweli is more than 10 000 km and it irrigates an area of more than 365 000 ha. By 2018, a total of 159 000 farming families had been enabled to settle in Mahaweli as well.

3.1.2 Polgolla Diversion Complex

The Polgolla Diversion Complex is the first of the fifteen multi purpose water resources development projects undertaken in Mahaweli. The project was undertaken between 1971 and 1977, the main components of the project are the Polgolla Diversion Dam across the Mahaweli Ganga, an eight-kilometre underground tunnel to divert a flow of 57 m^3/sec from the Mahaweli to the Sudu Ganga in the dry zone, and a 40 KW hydropower station at Ukuwela in the Amban Ganga basin. The tail water from the hydropower plant is diverted at Bowatenna through a six-and-a-half kilometre tunnel and an inter-basin canal to the Kala Oya basin and the Kalawewa and Kandalama reservoirs for irrigation. The project also included the development of 36 850 ha of new irrigated land in addition to the existing 53 450 ha that benefited from improved water availability. Further downstream, the diverted water benefits System D, G, H, IH, M, Elahera and Angamedilla reservoirs for irrigation. Currently, about 3 200 million m^3 of water from Mahaweli Ganga is diverted annually to irrigate a gross area of 146 000 ha. In the final stage of development, this amount will increase to 4 300 million m^3 to meet an annual irrigation demand of about 5 300 million m^3 and 160 million m^3 for drinking water supply (5 460 million m^3 in total). It should be noted that the balance between the diversions and the demand, which is 1 160 million m^3 (5 460-4 300) will be met through local recharge and storage in various irrigation tanks.

3.1.3 Participatory management of irrigation systems

The ancient irrigation system in Sri Lanka was developed with the construction of village tanks, diversion structures, anicuts, and conveyance and distribution canals. With the introduction of new construction technologies in the development of water resources, the ancient system evolved gradually into an engineered system. The management of this unique irrigation system was also transformed with the development of water resource infrastructure. Operation, maintenance and rehabilitation of the irrigation systems were the responsibility of state institutions until 1980. However, this was largely inefficient as rehabilitation programmes progressed slowly, farmers were not fully included in the decision-making process and irrigation fees collection was extremely low.

In the 1980s, the PIM model was introduced to improve irrigation cost recovery and farmers' participation in irrigation decision-making. In 1981, a national programme for the transformation of irrigation system was launched in 24 major irrigation schemes covering 80 000 ha. The necessary setup for farmers' institutions were created and strengthened on the ground. The programme achieved positive results in terms of efficient water use through better water management, higher cropping intensity, more equitable water allocation and distribution, transparency in water allocation and high acceptance of intervention strategies by farmers. As a result of the success of this pilot programme, the government began implementing the Integrated management of agricultural settlements (INMAS) in 1984, covering 37 major irrigation systems totaling 155 000 ha. This was the first official attempt at national level to mobilize farmers for integrated management of irrigation schemes, including smallholder settlement schemes. The objective of the INMAS programme was to provide a framework for coordinating the activities of the government agencies involved and to facilitate farmers participation in the management of irrigation system. Key elements of this programme included the establishment of farmers' organizations and project management committees.

After a decade of experimentation and experience, the PIM model was adopted as the national irrigation management policy in 1992. This policy requires the government to continue supporting the operation and maintenance of diversion headworks and main irrigation canals. The water allocation from tanks, operation and maintenance of tanks and irrigation network is the responsibility of farmers' organizations (FOs), the FO is also responsible to ensure implementation of decisions taken at kanna meetings. The PIM model has led to a change in investment patterns. Less funding is now being allocated to infrastructure development and more attention is paid to management aspects. The PIM has partially achieved its objective but cannot be called a complete success. Some reasons for the partial failure are: the surface water oriented approach that does not include groundwater management, farmers in the existing systems are still largely dependent on government aid and institutional instructions to perform their tasks, political influence in the election of community members resulted in inadequate change in attitudes towards water management, and insufficient cost recovery is still a problem that leads to financial difficulties for community organizations.

3.2 INSTITUTIONAL ARRANGEMENTS FOR SEASONAL PLANNING

Preparations for seasonal planning begin at least six weeks before the start of each growing season. Planning meetings are held around 1 March and 1 August for the Yala and Maha cropping seasons, respectively, to prepare and initiate preliminary water management measures. The district and divisional secretaries collect the information from the directors of irrigation at the regional levels. The information includes:

- a suitable date for the seasonal meeting (kanna meeting);
- last date for completion of irrigation maintenance works;
- projections of water inflow, water availability and possible diversions as a result of expected rains;
- proposed extent of cultivated areas and cropping patterns;
- recommended dates for commencement and completion of irrigation permits;
- suggested dates for completion of land preparation; and
- details of rotational water issues.

3.2.1 Special project management committee meeting (pre-kanna meeting)

According to the Irrigation Act, the Irrigation Project Manager convenes a special meeting of the Project Management Committee (pre-kanna meeting), which is attended by farmers' representatives and officials of the Irrigation Department who are also members of the Management Committee. Usually, this meeting is held to discuss the above information and to receive feedback and comments from other technical authorities. The results of the special meeting of the Project Management Committee are communicated to the relevant district and divisional secretaries.

3.2.2 Project Management Committee meeting (kanna-meeting)

The kanna meeting of the Irrigation Scheme Management Committee is a centuries-old practice, and the management committee is the most effective decision-making body at the tank level in irrigated agriculture. Before each cropping season, the owners of all irrigated lands in the irrigation scheme are called to a meeting by the district or divisional officer to plan the optimum use of irrigation water. Two-thirds of the farmers must be present for the decisions taken at the meeting to be legally valid. The meeting is conducted in a democratic manner and is chaired by officials from the Department of Agricultural Agrarian Services and government officials. In case of major rehabilitation works on irrigation scheme are intended, representatives of the Irrigation Department are invited. During the meeting, joint decisions are taken on irrigation water management, cropping calendar, extent of paddy cultivation, paddy varieties, harvesting and rehabilitation and repair of irrigation infrastructure. Historically, water allocation for old paddy fields (Puranawela) takes priority, while allocation for newly leased paddy fields is decided based on the expected volume of water that would be collected in the tank during the season.

The decisions taken in the kanna meeting are approved by the district and divisional officials. Unresolved matters, such as disagreements between farmers or insufficient quorum, are decided by these officials using their authority. All decisions taken in the meeting are respected by the farmers, but sometimes deviations from the decision occur because farmers do not attend the meeting and influential farmers add new paddy fields to the system (Akkarawela). Such last-minute deviations lead to inefficient and non-optimized use of tank water. If a disproportionate number of new paddy fields are added to the system for which water was not approved during the kanna session, this would lead to severe water shortages in the final stages of crop growth and may result in crop failure. Adherence to water management practices is necessary to use tank water efficiently throughout the season and conserve water for the dry season, but most farmers prefer to use water under the continues delivery condition, which leads to inefficient water use. Continuous delivery of water is usually due to poor implementation of water delivery schedule at the sluice gates of the tanks.

3.2.3 Special meetings

In addition to the usual kanna meetings held before the start of the cropping season, the District Secretary may convene special meetings by virtue of his powers under the Irrigation Ordinance or at the written request of farmers representing one-fifth of the irrigated area within an irrigation scheme, to discuss urgent and serious rice cropping issues during the ongoing cropping season.

3.3 KANNA-MEETING AT MAHAWELI AND WALAWE SYSTEMS

The irrigation schemes under the Mahaweli and Walawe Ganga are interlinked to each other by the feeder canals and are managed by the Irrigation Department and the Mahaweli Authority. These schemes are not independent and water management issues in an upstream scheme could affect the cropping pattern in the downstream scheme. Therefore, water management issues and cropping pattern of all the schemes are made by taking into account the system as a whole. With this in mind, seasonal water issues for the Mahaweli and Walawe irrigation systems are planned using a computer simulation model that takes into account the existing water situation in the reservoirs, predicted rainfall patterns, inflow during the season, power generation, drinking water requirements and other factors. Decisions are made by the Mahaweli Authority Water Management Secretariat with the participation of all stakeholders. This integrated plan is shared with the water panels, farmers' representatives, district administrators, divisional administrators, other concerned government agencies and water supply boards officials during the seasonal planning meeting chaired by the Director General of MASL at the beginning of each season. On this occasion, the plan is discussed, possibly amended and decided agreed upon.

The Project Coordination Committee meetings for each scheme are then held prior to the start of cropping season and seasonal water issues, and the cropping calendar at the scheme level is planned based on the instructions received from the Water Management Secretariat. The Project Coordination Committee is chaired by the Resident Project Manager and consists of farmer representatives and officials from relevant government departments and corporations. This meeting is considered equivalent to the kanna meeting for these specific plans. The system level agreed plan is reviewed by the MASL Water Management Secretariat on weekly basis for its smooth implementation.

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4. Cross-cutting issues in paddy farming

4.1 TRENDS OF CLIMATE CHANGE IN SRI LANKA

Overall, the information on observed and projected changes indicates that Sri Lanka's climate is undergoing three main types of changes: a gradual increase in temperature, changes in the distribution pattern of rainfall and an increase in the frequency and magnitude of extreme weather events. In addition, there are also changes in the oceanic environment and sea level rise, which is expected to have a significant impact on Sri Lanka. Climate change is a multidimensional phenomenon, its impact is not limited to the environment but it also affects agriculture, tourism, society and health. In Sri Lanka, the average annual temperature in coastal areas is between 26.0˚C and 28.0˚C. At higher altitudes, above 1500 m, the temperature ranges between 15˚C and 19˚C. These temperatures experienced an overall increase of 0.16°C per decade from 1961–1990, with the highest increase in minimum temperature being 2.0°C at Nuwara Eliya. Sri Lanka’s 100-year warming trend from 1896 to 1996 is 0.03°C per decade. However, in the last 10-year period from 1987 to 1996, it was 0.25°C, indicating faster warming in recent years. The country’s average annual temperature is projected to increase by 1.08°C by 2030. Maximum temperature is projected to rise by 0.68°C to 0.78°C and minimum temperatures by 0.69°C and 0.80°C. There is a decreasing trend in precipitation in most parts of the country, except the northeast. Compared to the period 1931–1960, the average annual rainfall has decreased by 144 mm (7 percent). Although no significant changes in rainfall have been observed during inter-monsoon 2 (IM2), rainfall has decreased during inter-monsoon (IM1) and there may be changes in the amount and spatial distribution of rainfall. These changes may lead to a 13-23 percent increase in water demand for irrigation of paddy in the Maha season by 2050 compared to 1961–1990.

4.1.1 Climate change impact on agriculture and water resources

Climate change has already begun to impact the agriculture sector of Sri Lanka. In 2016-17, 82 560 hectares of paddy area was hit by severe drought, resulting in 20 percent loss of paddy production amounting to more than 719 000 tonnes. Nearly 72 percent of paddy is grown during the Maha season in dry areas where water resources are already stressed. According to the projections of the National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016–2025, water demand during the Maha season will increase by 13-23 percent by 2050 as average rainfall will decrease, potential evapotranspiration increase and the rainy season will be shortened.

The demand for irrigation water of other crops grown in the dry and intermediate zones during the Yala season will also increase significantly. Tea cultivation at low and medium altitudes is more vulnerable to reduced precipitation than cultivation at higher altitudes. A 100 mm decrease in monthly rainfall could reduce productivity by 30-80 kg/ha of processed tea. Changes in precipitation pattern and cloud cover during the rainy season may reduce coconut yields, with projected annual losses ranging from USD 32 to 73 million. The projected changes in rainfall amount and shift in rainfall pattern in the Central Highlands is likely to lead to conflicts between hydropower generation and water supply for irrigation from the Mahaweli Multi-Purpose Project, which meets 29 percent of national electricity demand and supplies 23 percent of irrigation water to the major schemes.

The following measures are proposed in the National Adaptation Plan on Climate Change to reduce negative impact on agriculture and water resources:

- Strongly promote efficient water management strategies in all forms of agriculture.
- Develop and introduce drought and pest resistant varieties of rice and other crops.
- Heat stress and disease tolerant breeds of livestock and poultry should be promoted.
- Adjustment in cropping calendar according to climate forecasts.
- Develop an effective early warning system for climate monitoring, analysis and dissemination of climate-related information to farmers.
- Build capacity for climate change research and development of drought and heat resistant crop varieties and livestock breeds.

- Develop and implement effective watershed management plans for vulnerable watershed areas.

- Identify and map areas vulnerable to drought and flood hazards and prepare disaster risk management plans.

- Design rational intra-basin and trans-basin strategies to harness periodic surpluses of water in storage facilities.

4.2 SOCIAL INCLUSIVENESS IN PADDY FARMING

4.2.1 Role of women in agriculture

In Sri Lanka, the unemployment rate of women is twice that of men at all age groups. A large number of economically active women work as unpaid family labour in agriculture. Of the total women employed in the country, 30 percent work in agriculture and most of them are engaged in subsistence farming. There are major gender disparities in access to and control over resources such as land, water, access to markets and access to skills development programmes; all of them are critical to agricultural production and livelihoods. Irrigation organizations only accept registration applications for water sanctioning from farmers who own land for paddy cultivation. As a result, women without land titles do not have legal access to irrigation water, despite being engaged in various agricultural activities throughout their lives. Rural women perform a variety of agricultural activities, with the exception of operating farm machinery. Women contribute to paid work as day labourers in private farms or as wage labourers in commercial farms, unpaid work in family-owned croplands, kitchen gardening and unpaid social reproductive work such as cooking, cleaning and childcare. Among households whose main source of income is agriculture, 68 percent of women are involved in daily farming. Women start working in agriculture in their early teens. At the same time, many of them do unpaid care work for siblings and support adults in their households to earn a living. In all religious, ethnic and local groups, participation in agriculture is lower when women have young children. Prevailing gender norms reinforce women's responsibility for childcare, leading them to work from home to earn an income without travelling long distances. Up to the age of 40, participation in agriculture increases exponentially, while participation in other livelihood activities decreases overall. Older women have the highest participation in agriculture.

4.2.2 Human development and gender gaps

The Human Development Report 2020 presents the Human Development Index (HDI) for 189 countries and UN-recognized territories. Sri Lanka's HDI score for 2020 is 0.782, placing the country in the high human development category and ranking 72nd out of 189 countries and territories. Between 1990 and 2019, Sri Lanka's HDI score increased from 0.629 to 0.782, an increase of 24.3 percent. Between 1990 and 2019, Sri Lanka's life expectancy at birth increased by 7.5 years, average years of schooling increased by 2.3 years and expected years of schooling increased by 2.8 years. Sri Lanka's GNI per capita increased by about 229.4 percent between 1990 and 2019. Of the

8.6 million economically active people, 65 percent are men and only 35 percent are women. Across all age groups, women make up 52 percent of Sri Lanka's population, but female representation in parliament is only 5 percent. In 2017, female labour force participation is 37 percent of the total population.

4.2.3 Participation of youth in agriculture

The young population aged 15-29 years in Sri Lanka constitutes about 4.64 million or 23 percent of the total population. Sri Lanka has a dynamic age structure with a very large age group of 25-54 years forming the backbone of the country. About 43 percent of the population belongs to this age group. Despite being a developing economy, such a large working population enabled Sri Lanka to undertake development projects and create jobs, which have contributed not only to livelihood security but also to the steady growth of the national economy in recent years.

In addition, the average age of people in Sri Lanka is 31 years, with an average age of 30 years for men and 32 years for women. Sri Lanka also has a high life expectancy of 76 years, with a male life expectancy of 72 years and a female life expectancy of 80 years. The elderly population (54-65 years) accounts for about 9 percent of the country's population, while 8 percent are over 65 years of age. The gender composition of the youth population is almost evenly split, with 50 percent males and 50 percent females. Youth unemployment remains a critical issue, both for policy makers and for the young population itself. In 2010, the unemployment rate was 20 percent in the 15-19 age group and 19 percent in the 20-24 age group. Female unemployment in the 20-24 age group is even higher than male unemployment. Poor income prospects have made it difficult for the agricultural sector to attract skilled youth. Mechanization of the sector has been promoted by the government to attract the younger generations, but the small size of landholdings remains a major obstacle to the adoption of highly mechanized agriculture. To remain competitive and attract young and skilled labour, the agriculture sector needs to create opportunities for integrating livestock and aquaculture into large farms.

4.3 WATER CHARGES

To improve water use efficiency and reduce water losses in surface irrigation systems, the Government of Sri Lanka introduced an operation and maintenance charge on all major irrigation systems in 1984 with the promise of improving irrigation infrastructure and services. The need to impose these charges arose from the inability of the state to allocate adequate funds for the optimal operation and maintenance of the major irrigation schemes. The failure to allocate sufficient funds for operation and maintenance has led to rapid deterioration of irrigation infrastructure, excessive water losses and poor service delivery in the long run. The collection of fees began with promising results, but it did not last long. By the end of 1985, fees collected amounted to 40 percent of the amount due. By the end of 1986, only 15 percent of fees was collected, while the collection rate in 1987 was only 11 percent. Alternatively, the introduction of a uniform rate for the collection of operation and maintenance charges for all systems was also considered, but the locations, different physical conditions of the systems, climate and water availability were identified as major obstacles to the success of this approach. Currently, there are no water charges for farmers with a land area of less than 10 ha. The Irrigation Department provides water for

LKR 25/m^3 (USD 0.1/m^3) to commercial farmers who have more than 10 ha landholding. The main reasons for this situation are the failure to deliver the promised improved irrigation services, the inability to use the revenue collected to improve the system, the weak enforcement mechanisms for fee collection and the failure to take action against defaulters. Moreover, with gravity-fed surface irrigation systems, it is virtually impossible to prevent access to water due to default unless the defaulters are evicted. Farmers' lack of interest in participating in water management activities and inadequate financial resources to operate and maintain irrigation systems have led to excessive water consumption and low water use efficiency, which in turn results in low marginal productivity.

4.4 COMPLEXITY OF IRRIGATION SYSTEM AND ITS MANAGEMENT

In Sri Lanka, irrigation is a complex system developed, managed and operated in parallel by different institutions. The Irrigation Department was established in 1900 under British rule. Its purpose was to develop and manage water resources for irrigation, involving farmers' committees. In the first 50 years of its existence, the department developed and rehabilitated several storage tanks using engineering principles. After independence in 1948, the department shifted its focus to the construction of new reservoirs and by 2000, several reservoirs, tanks and diversion structures were constructed. Some notable projects among these are the Senanayaka Samudraya (the largest reservoir in the country), the Rajangana, the Inginimitiya and the Lunugamvehera reservoirs, and the Neela Bemma anicut. During this period, several laws and ordinances were enacted to improve irrigated rice cultivation. Under these laws, responsibility for maintaining irrigation systems shifted from the Ministry of Agriculture (MoA) to the Territorial Civil Engineering Organization (TCEO) and finally, in 1979, to the Department of Agricultural Services (DAS), which also took control of the Farmers' Committees. Today, the major and medium irrigation systems are built, operated and maintained by the Irrigation Department. There are currently more than 300 major irrigation schemes in operation, about 52 of them are jointly managed by the Irrigation Department and the Irrigation Management Division of the Ministry of Irrigation under the Integrated management of agricultural settlements (INMAS) programme. The irrigation department is responsible for the management irrigation schemes on 294 000 ha of land. The main activities of the department include seasonal planning for paddy cultivation, conducting seasonal planning meetings, development of water suppy schedules, review and rectification of supply schedules, coordination of water allocations in major and medium irrigation schemes, operation and monitoring of storage in major and medium reservoirs and overall performance assessments of irrigation systems.

To further develop the water resources of the country, the Mahaweli Development Project was conceived in 1960s and development works on the first system was started in 1971. The Mahaweli Development Project consists of more than 10 000 kilometre of irrigation canals, several kilometres of inter-basin water transfer link canals and tunnels and about 20 multipurpose major and medium reservoirs. The management, operations and maintenance of all the multipurpose water resources systems in Mahaweli including irrigation system on about 365 000 ha are under the supervision of the MASL. The Mahaweli Authority works parallel to the irrigation department and is undertaking water management and multiple socioeconomic and environmental activities in ten systems. The Moragahakanda and Kaluganga are the most recently developed systems with irrigated area of about 80 000 ha, which are provided irrigation water from Mahaweli river system for both Yala and Maha seasons.

The Sri Lanka National Freedom from Hunger Campaign 1973, estimated 18 000 village tanks throughout the country to store water for minor irrigation systems of less than 80 ha. Currently, about 12 000 tanks are in abandoned state in the dry zone and only 6 000 are functional. The minor irrigation schemes are developed by the irrigation department but the management of these schemes and Farmers Organizations (FOs) are under the Department of Agrarian Development, adding yet an other layer to the complexity of irrigation systems management. About 10 000 field officers of the department and 13 000 farmer organizations are engaged in the operation and maintenance of irrigation facilities and water management practices of the minor irrigation schemes but still a large number of storage tanks are dysfunctional due to overlapped responsibilities and lack of fund for rehabilitation. Some of the standard water management practices in the minor irrigation schemes are: flow gates calibration and monitoring, efficient utilization of green water for paddy cultivation, excluding well drained soils from paddy cultivation, standard water allocation at the rate of 3 700 m^3 per 4 046 m^2 in dry zone, 2 467 m^3 per 4 046 m^2 in intermediate zone and 0.02 m^3 of baseflow per 12 ha in wet zone.

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5. National policies for developing an agricultural based economy

5.1 PUBLIC INVESTMENT PROGRAMME (2017–2020)

The Public Investment Programme (2017–2020) of Sri Lanka was introduced by the Department of National Planning of the Ministry of National Policies and Economic Affairs to introduction essential policy reforms and the promotion of investments for the improvement of productivity in all sectors.

The five development goals outlined in the programme are:

1. generating one-million employment opportunities;

2. enhancing income level;
3. developing rural economies;
4. ensuring land ownership to rural and estate sectors, the middle class and government employees; and
5. creating a wide and strong middle class.

These goals are closely related to the targets of 2030 Sustainable Development Agenda and show high commitment of the country to develop the agricultural based economy.

5.1.1 National policy framework: Vistas of Prosperity & Splendour

Development through advanced technological innovations, building up a healthy and productive nation, guaranteeing the people's right to safe food, and international export business through various value-added products are identified as key strategies to take agriculture to the next level to support the economy in a vibrant manner. In addition, changes in food consumption habits and diets, including less carbohydrates and more fibre, are indicated as useful strategies to reduce the high dependence of agriculture sector on water.

The government's National Policy Framework includes 10 key policies aimed at achieving four outcomes: (1) a productive citizenry, (2) wealthy livelihoods, (3) a safe and just society, and (4) a prosperous nation.

They key policies are:

- priority to national security;
- friendly, non-aligned, foreign policy;
- corruption-free administration;
- a new constitution;
- productive and constructive citizenry;
- people-centred economic development;
- technology-based society;
- development of physical resources;
- sustainable environmental management; and
- disciplined, law-abiding and values-based society.

The agricultural sector is expected to continuously play an important role in the socioeconomic development of the country. A rapid growth of the sector, particularly in domestic food production, floriculture and agricultural export, is essential to achieve self-sufficiency at the national level and to ensure food security and increase equity in the distribution of income and wealth for alleviating poverty. In the 'Vistas of Prosperity & Splendour' strategy, agriculture is included as a sub-sector of people centric economy and recognized as a priority area for realizing multiple goals, including:

- food security of people;
- higher and sustainable incomes for farmers;
- remunerative prices for agricultural produce;
- uninterrupted access to competitive markets, both domestic and international;
- farm mechanization;
- expanded cultivated areas;
- reduced waste from processing;
- environment conservation;
- efficient farm management techniques;
- high yielding seeds and improved water management;
- reduced sugar import, with benefit on government revenue;
- free fertilizer for all paddy farmers;
- developed home garden (up to 2.5 million ha);
- government procurements of paddy, vegetables, fruits etc. under guaranteed prices and distribution of food under price ceiling; and
- self-sufficiency in 16 crops and food import restrictions.

In this context, the shift from raw to value-added agriculture products is highly prioritized to improve competitiveness in the international market. Reflecting on the need to achieve these goals, an equitable allocation of water resources across key economic sectors, including irrigated agriculture, is needed. This issue is highlighted in the Agriculture Water Policy as:

- currently unsustainable extraction of groundwater resources;
- regulatory framework(s) for water pricing for large scale commercial agricultural production;
- adverse impacts of agriculture to surface and groundwater quality;

- requirements for aquaculture in water resources development planning and design;
- poor water management and use practices and low water use efficiency;
- lack of funds for efficient operation and management of irrigation systems;
- scarce coordination among and within institutions responsible for agricultural water management at national and provincial levels;
- short-sighted planning, not always based on scientific resource assessment, insufficient legal framework and resourcing for effective IWRM; and
- insufficient resources to authorities charged with conserving areas critical for the health of water resources, reservations of waterways and reservoir/tank catchments;

In line with national priorities, the Agricultural Water Policy Statement promotes long-term water resource planning and efficient water management.

5.2 SUSTAINABLE SRI LANKA: 2030 VISION AND STRATEGIC PATH

The most comprehensive vision of Sri Lanka, the "Sustainable Sri Lanka: 2030 Vision and Strategic Path" was presented in August 2018, outlining a "Balanced Inclusive Green Growth (BIGG) path" approach. The vision shapes Sri Lanka's collective future as a sustainable, upper-middle-income Indian Ocean hub, economically prosperous, competitive and advanced, environmentally green and flourishing, and socially inclusive, harmonious, peaceful and just. Relating to agriculture and food, the Vision recognizes that current food production system are under the threat of unsustainability. Food production systems require a shift to highly mechanized and drought tolerant crop varieties with low water demand. In addition, the capacity building constraint of small farmers are recognized and training programmes for rural families are integrated within the value chain of commercial growers. With reference to the rice sub-sector, the Vision indicates the following objectives:

1. Increase of crop productivity and quality (with sensory, nutritional and safety characteristics) of rice through improved rice varieties, increased use efficiency of external inputs to address hunger, increase profitability, food security in staple food requirements and improving living standards of the rice farming community.
2. Develop high yielding varieties resistant to biotic-stresses such as pest and diseases, tolerant to abiotic stresses including resilience to emerging climate change, and adapted to irrigated and rainfed farming.
3. Promote mechanization as a solution to labour shortage and to increase youth employment in the sector.
4. Develop and link to the value chain for rice-based value-added through public-private partnerships, and considering consumers' preferences, demand for traditional varieties as well as suitable varieties for the export market.

Accordingly, the following strategies were proposed by the government to improve the productivity of agriculture and proper land use:

a) diminishing trend in land availability for agriculture;
   - development of proper land use policy and effective implementation;
   - identification of prime agricultural lands (development of valuation system);
   - use/ conversion of land based on land suitability assessment; and
   - urban and peri-urban agriculture;

b) underutilization/ misuse of arable lands;
   - identification of root causes for underutilization of existing lands;
   - improvement of management for proper utilization; and
   - development of guidelines for effective management of lands;

c) unappropriate allocation of lands among uses;
   - development of a database on supply and national demand for agricultural commodities;
   - research on seasonal zoning crop combinations and development of relevant database; and
   - development of new policies on allocation of lands among sectors based on national priorities;

d) degradation of land productivity;
   - mapping of degraded lands under different land uses and research on land-use change on soil productivity; and
   - research on land restoration techniques;

e) land fragmentation /Uneconomical land holding size;
   - research and policies on potential and constraints for land consolidation; and
   - studies on cooperative farming systems;

f) land entitlements;
   - formulation of sound policies; and
   - encroachment of reservation and riparian areas;

g) comprehensive spatial database on land resource;

h) research on new techniques on digital land resources mapping (soil, land use, topography); and

i) development of detailed land resource inventory, web-based user-friendly land resource information.

Strategies recommended for agricultural water management are:

a) temporal and spatial variation of availability of water;
   - updating of vulnerability maps;
   - investigation of adaptation strategies; and
   - research on improvement of catchment hydrology;

b) insufficient water;
   - new strategies on water conservation farming; and
   - new strategies to increase water use efficiency;

c) low water productivity;
   - studies on improvement of on-farm water management system;
   - studies on crop modelling for different farming systems;
   - studies on drainage measurement;
   - low-cost methods for sea water purification and application to agriculture; and
   - research on precision farming;

d) lack of preparedness for extreme events of flood and droughts;
   - updating and up scaling of drought and flood vulnerability maps;
   - development of drought and flood-tolerant varieties; and
   - development of suitable land management techniques;

e) water quality deterioration; and
   - detailed mapping of surface and groundwater quality;
   - remediation techniques for water pollution;
   - study on the impact of excessive use of agrochemicals on water resources;
   - development of water quality goals for identified water resources; and
   - studies on the use of waste water for agriculture;

f) lack of policy/regulation for groundwater extraction;
   - development of a database for groundwater use and monitoring;

5.3 OVERARCHING AGRICULTURE POLICY

The overarching agriculture policy of August 2019 is part of a strategic government's response to the evolving priorities and challenges in the global, national and sectorial environments, while working towards the national vision of transforming Sri Lanka into a "knowledge-based, export-oriented competitive economy at the centre of the Indian Ocean".

The policy identifies 5 core areas for strategic policy action:

1. Increase productivity of farming of both land and labour.

2. Energize domestic farm-market linkages and the rural economy.

3. Increase export earnings (tea and potential crops as fruits, vegetables, floricultural products, rice and other food crops).

4. Mainstream gender and youth.

5. Implement effective mechanisms to coordinate, guide and monitor sector development.

The objectives are to enhance the competitiveness of agriculture and agri-businesses through innovative and sustainable technologies and constructive partnerships, in a conducive institutional and regulatory environment, with a view to enhance economic growth and raise living standards of people engaged in agriculture.

5.3.1 National agricultural research policy and strategy 2018–2027

The national agricultural research policy and strategy 2018–2027 was formulated to identify policy statements and strategies that focus on agricultural research priorities in multiple sub-sectors. It considers: plantations, non-plantations, livestock, poultry, fisheries, aquatic resources, forestry and floriculture. Food security underpins several issues, mainly due to the impacts of climate change. The strategy also indicates the priorities of cross-cutting research policy areas in natural resources management, plant genetics, quarantine services, seed certification, organic agriculture, farm mechanization, food waste management, socioeconomic planning, agricultural trade, investment, public-private sector engagement, employment, land and rural development.

In the strategy, agriculture is presented as a sub-sector under the policy item of people-centred agriculture. Development through advanced technological innovations, building up a healthy and productive nation, guaranteeing people’s right to safe food, and promoting international export through various value-added products backed up by new technologies, are identified as key strategies to take agriculture to the next level as a key supporting sector to the national economy.

5.4 GENERAL IRRIGATION POLICY, STRATEGY AND PROGRAMMES

Water allocation and access rights are addressed in a number of legislative enactments developed over many years in response to a variety of water issues. There are over 50 laws relating to such diverse aspects as irrigation, land, agriculture and drinking water supply. The most important legislation and its key provisions can be summarized to illustrate the legal dimension of water institutions in the country. The irrigation ordinance No. 32 was first enacted in 1856 by the British colonial administration to both legalize customary irrigation practices and to prescribe the conditions for water extraction, particularly for paddy cultivation. This ordinance has been amended from time to time to keep pace with the changing socioeconomic conditions and requirements. The state lands ordinance No. 8, Part IX of 1947 defines public and private water and specifies the water uses for which no permit is required. Currently, four government institutions, namely, the irrigation department, department of agrarian development, Mahaweli authority and provincial irrigation department have responsibilities over irrigation, and each of them has its own practices in the planning of kanna-meetings.

At present, there are several legal policies available for the proper management of irrigation. Act No. 48 of 1968, referred to as the "Principal Enactment" of irrigation ordinance and its amendments, act No. 23 of 1983, act No. 34 of 1990 and act No. 13 of 1994 provide substantial legal support in the irrigation sector. In addition, the agrarian development act No. 46 of 2000 and the Mahaweli authority act No. 23 of 1979 provide legal backing for the irrigation sector. Table 10 summarizes the irrigation related acts and their main points.

Table 10. Irrigation Ordinance and its Amendments

Irrigation ordinance	Description
First irrigation ordinance No. 9, 1856	- To revive the enforcement of ancient customs on irrigation and cultivation of paddy lands. - To improve and remove delays in the settlement of differences and disputes among cultivators relating to water rights.
Paddy cultivation ordinance No. 21, 1867	- Government assistance could be requested when owners are unable to construct, repair or improve any irrigation works individually. - The governor had the authority to direct his officers to prepare proposals and estimates for the repair/improvement works. - Government officers carried out the work and land owners were given the option to attend the earthwork. - The land owners were liable to pay the expenditure incurred to repair or improvement works in instalments and any case of default. - Any survey plan covering tanks, channels, watercourses, etc. prepared by the surveyor general was considered as legally authorized proof of the irrigation scheme.
Irrigation and paddy cultivation ordinance No. 23, 1889	- Formation of irrigation boards at central and provincial levels, namely Central Irrigation Board (CIB) and Provincial Irrigation Board (PIB). - Demarcation of irrigation districts by governor, with or without any request from proprietors. - Establishment of irrigation fund and colonial treasurer to provide annual financial resources for the irrigation fund to be vested with CIB. CIB to prepare estimates for irrigation works. - Government Agent (GA) was empowered to decide releasing of government funds for the irrigation works maintained by proprietors.

(continues)

Table 10. Irrigation Ordinance and its Amendments *(cont.)*

Irrigation ordinance	Description
Irrigation ordinance No.16, 1906	- The Central Irrigation Board and Provincial Irrigation Board were abolished and the irrigation fund was ceased. - The power of demarcating irrigation districts by GA and proprietors was withdrawn and the governor was empowered to do the same. - The governor was empowered to declare any irrigation scheme to be placed under control and management of the director of irrigation (irrigation department was only formed in 1990). With that, similar to the power of GA on other schemes, the director of irrigation had powers to make rules for land-owners meetings, establishment of a committee for the revival of customs, maintenance of irrigation works, water distribution and appointing irrigation officers who were similar to the irrigation headman. - GA was empowered to fix the rate for maintenance based on the estimate prepared by the director of irrigation. - With the discretion of the village council, salaries for the services of irrigation headman were decided and owners were legally responsible to pay, either in kind (produce) or money. - The land owners were able to decide and request funds from the government for any irrigation works if necessary. When the government fund was not expected, the contribution of land-owners was determined by them and approved by the GA. The rate of contribution was on the basis of either per acre per year or a lump sum per acre or both. - Village committees formed under the village communities ordinance were authorized to provide financial assistance for people to cultivate crown lands. - In addition, government provided grants for paddy cultivation. - Rules' violations were referred to village tribunal through the GA and punishments for offences had been explained clearly.

(continues)

Table 10. Irrigation Ordinance and its Amendments *(cont.)*

Irrigation ordinance	Description
Irrigation ordinance No.45, 1917	- GA was empowered to fix the irrigation rates. - Director of irrigation was empowered to issue permits for diverting water from public streams for individuals for irrigation purposes. - Director of irrigation was able to appoint an arbitrator in a court of arbitration. - Governor had the authority to take steps to rectify the defects of poorly maintained irrigation works by proprietors and recover the cost from them. The governor had to obtain the opinion of director of irrigation in this regard. - Protection of irrigation works and conservation of water were explained and the governor was empowered to make rules on the utilization of irrigation (diversion, prevention of obstructions to irrigation works etc).
Irrigation ordinance No.32, 1946	- District Agricultural Committees (DAC) were set up for each administrative district under the chairmanship of the GA. Members of this committee consisted of government officers who were dealing with agricultural development in the district such as director of irrigation, district agricultural extension officer, assistant commissioner of co-operative development, assistant commissioner of agrarian development, assistant commissioner marketing etc. and representatives of interest groups relevant to agriculture. - Advisory committees were established for each scheme and included the director of irrigation, director of agriculture, GA and at least 12 members elected among owners. The GA chaired the committee. - The powers of the irrigation headman were clearly defined. - Major and minor irrigation works were defined separately for major schemes constructed and maintained by the director of irrigation through national funds. - Rules were enforced on those paddy lands not yet included under irrigated systems but under rain, well or any other sources (“manawari” lands). - Special attention was paid to irrigation offences by strengthening rural courts’ powers for the prosecution of persons for such offences.

(continues)

Table 10. Irrigation Ordinance and its Amendments *(cont.)*

Irrigation ordinance	Description
Irrigation ordinance No. 48, 1968	- One of the main changes made under this act was the power given to the commissioner of agrarian services to carry out their duties under the irrigation ordinance, in line with paddy land act No.01 of 1958. With this, some of the duties carried out by the GA under the previous irrigation act came under the commissioner of agrarian services. - Regarding the matters connected with irrigation, the cultivation committees and their agents were given powers under the new ordinance. - The post of irrigation headman was abolished and the irrigation agent appointed by the cultivation committee took over.
Irrigation act No.23, 1983 (amendment)	- The GA was empowered on the removal of obstruction or encroachment upon any channel, water course or tank and repairing damages to any irrigation structure and recovering the cost incurred to such removals or repair works. - Recovery of contribution from persons other than allottees and tenant cultivators were further elaborated, covering landowners and encroachers. - The word "rural court" mentioned in the principal enactment was replaced with the word "magistrate court". - Definition of irrigation fund from fines and penalties over irrigation offences.
Irrigation act No.34, 1990 (amendment)	- Section 118 of the principal enactment was amended on the definition of "Government Agent". Accordingly, "Government Agent" includes an additional government agent, an assistant government agent, secretary to the minister of the board of ministers of a province in charge of the subject of irrigation and divisional secretary of a provincial council.
Irrigation act No.13, 1994 (amendment)	- The expression "Cultivation committee" in the principal enactment of irrigation ordinance was replaced by the expression "Farmer Organization". - The powers given to cultivation committees under the Part IV, Section 23 of principal enactment passed to "Farmers' Organizations (FOs)". - Farmers' Organizations that have taken over O&M activities for distributary and field canals system in the command area of the organization, shall be exempt from irrigation tax. - Establishment of a "Project management committee" for the schemes specified by the secretary to the Ministry in charge of irrigation. - Definition for the cultivation committee in the principal enactment was deleted, and the term "Farmers' Organization" has been defined.

Source: author's own elaboration.

5.5 PADDY FARMING POLICY, STRATEGY AND PROGRAMMES

Sri Lanka has always given the highest priority to rice production, a staple food at national level. Therefore, all the policies and national development agendas related to agriculture have ensured the support for paddy production in the country. According to the public investment programme (2017–2020), the key strategy of paddy farming is that the annual paddy production will be maintained in future to ensure the food security of the nation, encouraging the cultivation of exportable rice varieties and organic rice export to the international market. This will be assured by recasting the present paddy production system by altering the cropping pattern and with the induction of new production technologies. The government intervention on paddy purchasing will be continued to ensure a fair price for the farmers. At the same time, crop diversification will be promoted to have optimum crop mix providing required incentives and new technical know-how to the farmers substituting the imports of other field crops.

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Appendix

Table A1. Classification of agro–ecological regions of Sri Lanka

Zone		Agro–ecological region	75% rainfall (mm)	Terrain	Soil group	Land use
WET ZONE	Upland	WU1	> 3 100	Mountainous, steeply dissected, hilly and rolling	RYP, mountain regosol and lithosol soils	Tea, forest plantation, natural forest
		WU2a	> 2 400	Steeply dissected, hilly and rolling	RYP soils	Tea, forest plantation
		WU2b	> 2 200	Mountainous, steeply dissected, hilly and rolling	RYP, mountain regosol and lithosol soils	Tea, forest plantation, vegetable
		WU3	> 1 800	Hilly and rolling	RYP soils with prominent A1 horizon and RYP soils with dard B horizon	Tea, vegetable, pasture, home gardens forest plantation
	Midland	WM1a	> 3 300	Mountainous, steeply dissected, hilly and rolling	RYP soil with semi prominent A1 horizon and lithosol soils	Tea, natural forest
		WM1b	> 2 900	Steeply dissected, hilly and rolling	RYP soil with semi prominent A1 horizon and Lithosol soils	Tea, natural forest, mixed home gardens
		WM2a	> 2 200	Steeply dissected, hilly and rolling	RYP, RBL and LHG soils	Tea mixed home gardens, export agricultural crops, natural forest, paddy
		WM2b	> 1 800	Steeply, hilly and rolling	RBL, IBL, LHG and RYP soils	Mixed home gardens, paddy, export agricultural crops, tea

(continues)

Table A1. Classification of agro–ecological regions of Sri Lanka *(cont.)*

Zone		Agro–ecological region	75% rainfall (mm)	Terrain	Soil group	Land use
WET ZONE	Midland	WM3a	> 1 600	Steep, hilly, and rolling	RBL, IBL, LHG and lithosol soils	Mixed home gardens, paddy, export agricultural crops, tea, rubber
		WM3b	> 1 400	Hilly rolling, undulating and steep	RBL, IBL, LHG soils	Mixed home gardens, paddy, export agricultural crops, tea, vegetable
	Lowland	WL1a	> 3 200	Rolling, undulating and hilly	RYP, RYP soils with semi prominent A1 horizon and LHG soils	Tea, rubber, mixed home gardens, paddy, cinnamon
		WL1b	> 2 800	Undulating and rolling	RYP and LHG soils	Rubber, mixed home gardens, paddy
		WL2a	> 2 400	Rolling, undulating, flat	RYP, LHG, Bog and Half - Bog soils	Rubber, tea, coconut, mixed home gardens, paddy, export agricultural crops
		WL2b	> 2 200	Steeply dissected, rolling and undulating	RYP, RYP soils with strongly mottled sub soil, RBL and LHG soils	Rubber, coconut, mixed home gardens, paddy
		WL3	> 1 700	Rolling and undulating	RYP soils with soft and hard laterite, LHG and regosol soils	Coconut, fruits, mixed home garden, paddy
INTERMEDIATE ZONE	Upland	IU1	> 2 400	Mountainous, steeply dissected, hilly and rolling	RYP, Mountain regolith and lithosol soil	Tea, cardamom, natural forest, and forest plantation
		IU2	> 2 100	Mountainous, steeply dissected, hilly and rolling	RYP, mountain regosol and lithosol	Tea vegetable, mixed home garden, natural forest, and forest plantation
		IU3a	> 1 900	Steeply dissected, hilly, and rolling	RYP and mountain regosol	Tea and forest plantation

(continues)

Table A1. Classification of agro–ecological regions of Sri Lanka *(cont.)*

Zone		Agro–ecological region	75% rainfall (mm)	Terrain	Soil group	Land use
INTERMEDIATE ZONE	Upland	IU3b	> 1 700	Mountainous, steeply dissected, and hilly	RYP, mountain regosol and lithosol	Tea, natural forest, and forest plantation
		IU3c	> 1 600	Steeply dissected, hilly, and rolling	RYP and LHG soils	Tea, vegetable, and paddy
		IU3d	> 1 300	Steep, hilly, and rolling	RYP, mountain regosol and lithosol soils	Tea, vegetable, forest plantation and natural forest
		IU3e	> 1 400	steep dissected, hilly, and rolling	RYP and LHG soils	Tea, vegetable, paddy, mixed home garden
	Midland	IM1a	> 2 000	Very steep and hilly	RBL, RYP, IBL, LHG and lithosol	Tea, vegetable, mixed home garden, paddy, and forest plantation
		IM1b	> 2 000	Hilly, rolling and undulating	RBE, RBL, LHG, mountain regosol and lithosol	Natural forest, mixed home garden, paddy, and grassland
		IM1c	> 1 300	Very steep, hilly and rolling	RBL, IBL, mountain regosol and lithosol	Natural forest, vegetable
		IM2a	> 1 800	Steep, hilly, and rolling	RBL and RYP	Export agricultural crops, mixed home garden, tea, and vegetable
		IM2b	> 1 600	Very steep, hilly, and rolling	RBL, IBL, RYP, LHG and Lithosol	Natural forest, mixed home garden, paddy, tea, and vegetable
		IM3a	> 1 400	Hilly, rolling, and steep	IBL, RBL and LHG	Mixed home garden, export agricultural crops and paddy
		IM3b	> 1 200	Rolling and undulating	RBL, RBE and LHG soil	Mixed home garden, export agricultural crops, rubber, vegetable, paddy
		IM3c	> 1 100	Steeply dissected, hilly, and rolling	RBL and IBL	Vegetable, tea, mixed home garden, export agricultural crops

(continues)

Table A1. Classification of agro–ecological regions of Sri Lanka *(cont.)*

Zone	Agro–ecological region		75% rainfall (mm)	Terrain	Soil group	Land use
INTERMEDIATE ZONE	Lowland	IL1a	> 1 400	Rolling, undulating and flat	RYP soil with strong mottled sub-soil, RYP, LHG, RBL and regolsol	Coconut, mixed home garden, export agricultural crops, paddy, and rubber
		IL1b	> 1 100	Rolling, undulating and flat	RYP, RBL, RBE, LHG and regosol	Coconut, paddy, mixed home garden, export agricultural crops
		IL1c	> 1 300	Rolling, undulating and flat	RBL, RBE, LHG and IBL	Mixed home garden, rubber, paddy, and sugar cane
		IL2	> 1 600	Rolling, hilly and undulating	RBE, LHG and RBL	Mixed home garden, paddy, rainfed upland crops, scrubs, sugar cane and citrus
		IL3	> 1 100	Undulating	NCB, RBE and LHG	Coconut, paddy, and mixed home garden
DRY ZONE	Lowland	DL1a	> 1 000	Rolling and undulating	RBE and LHG	Mixed home garden, paddy, forest plantation, scrub, sugar cane and natural forest
		DL1b	> 900	Undulating	RBE and LHG	rainfed upland crops, paddy, scrub, mixed home garden, forest plantation
		DL1c	> 900	Undulating	RBE and LHG	Rainfed upland crops, paddy, scrub, natural forest, forest plantation and sugar cane
		DL1d	> 900	Undulating and flat	RBE regosol and LHG	Rainfed upland crops, scrub, and paddy
		DL1e	> 900	undulating	RBE and LHG	Rainfed upland crops, paddy, scrub
		DL1f	> 800	Undulating	RBE, LHG and grumusol	Rainfed upland crops, paddy, scrub, and natural forest

(continues)

Table A1. Classification of agro–ecological regions of Sri Lanka *(cont.)*

Zone		Agro–ecological region	75% rainfall (mm)	Terrain	Soil group	Land use
DRY ZONE	Lowland	DL2a	> 1 300	Undulating	NCB, RBE, LHG and old alluvial	Rainfed upland crops, paddy, natural forest, sugar cane and scrub
		DL2b	> 1 100	Undulating and flat	NCB, RBE, old alluvial, LHG, regosol and Bolodize-Solonetz soil	Paddy, rainfed upland crops
		DL3	> 800	Flat and slightly undulating	RYL and regosol	Cashew, coconut, condiments, scrub, and natural forest
		DL4	> 750	Flat	Solodize-Solonets, Solonchaks and Grumusol soils	Scrub, paddy, rainfed upland crops
		DL5	> 650	Undulating and flat	RBE with high amount of gravel in sub-soil, LHG and Solodized-Solonetz soils	Scrub, natural forest, rainfed upland crops and paddy

Agro–ecological areas which are suitable for rice cultivation have been hihglighted in green. Zone and agro–ecological region colours correspond to those depicted in Figure 4.

IBM: Immature brown loam; LHG: Low humic gley; NCB: Non calcic brown; RYL: Red yellow latosol; RYP: Red yellow podzolic; RBE: Reddish brown earth; RBL: Reddish brown latosol

Source: Department of Agriculture, Sri Lanka

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