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Index Insurance

A Viable Solution for Irrigated Farming?

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Abstract

This paper documents the practical experience of deploying index insurance in a tropical country whose agriculture is dependent on dual sources of water: rainfall and irrigation. The paper introduces an innovative hybrid index insurance product based on the authors' experience of piloting the concept. The hybrid product was created to address the higher basis risk of using a single rainfall trigger that ignores the hydrological conditions on the ground. The paper brings forth findings from a live pilot in selected locations—with varied agro-climatic conditions—in Sri Lanka under the World Bank Group's Global Index Insurance Facility. The findings indicate that the new hybrid product performs better than the single trigger (rainfall-based) index insurance product, thereby reducing the basis risk faced by farmers. The paper also shares some of the practical limitations in deploying the product.

This paper is a product of the Finance, Competitiveness and Innovation Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at tarandara@ifc.org.

Insurance: A Viable Solution for Irrigated Farming?

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Finance, Competitiveness & Innovation Global Practice

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The work is part of a larger effort by the World Bank Group to provide open access to its implementation experience and contribute to development policy discussions around the world. The authors may be contacted at tarandara@ifc.org.

[1] To view more, please visit: https://www.indexinsuranceforum.org.

1. Introduction

The task of feeding the world's growing population – estimated at 10 billion people by 2050[2] – is further complicated by the risks of climate change. Adverse weather – and its impact on crop yields – is particularly painful for smallholder farmers in developing countries. A never-ending cycle of floods, droughts, storms, and other such extreme weather events can have devastating effects on farming and livelihoods connected to the agricultural ecosystem, leaving vulnerable populations in poverty (Barnett & Mahul 2007). Farmers in developing countries face these uncertainties on a regular basis, with limited recourse.

Apart from risk mitigation options such as improved early warning systems, adoption of better agronomic practices, etc., risk transfer solutions – if deployed effectively – can play an important role in addressing farmers' vulnerability to adverse weather. 'Risk transfer solutions' means the transfer of risk to a willing party, for a fee or premium[3] through mechanisms such as insurance. Studies have shown that addressing risk via insurance can increase smallholder investment and income by 20 to 30 percent, which is a pointer to how much such risks cost farmers when they face them entirely on their own (Carter, Janvry, et al. 2017).

Most agriculture insurance programs in the developing world are indemnity insurance programs, better suited for large-scale farmers. In countries where smallholders are predominant, such products are difficult to administer, resulting in inefficiencies such as slow claims settlements (due to the need for claims reporting and physical damage assessments), and complex/manual processes for claims estimation (which are sometimes skewed due to manipulations). In certain instances, agricultural insurance is either unavailable or prohibitively expensive. Negative experiences with traditional indemnity agriculture insurance schemes make farmers reluctant to continue purchasing them when offered commercially. For commercial insurers, small value agriculture insurance policies also become costly to maintain, and combined with the low uptake by farmers, leaves them no incentive to provide the service at all. Also, natural catastrophes such as droughts affect large numbers of smallholder farmers at the same time, posing practical difficulties for insurance companies to carry out individual loss assessments (Mapfumo et al. 2017).

Index-based agricultural insurance has lately gained popularity as an answer to these problems (Bielza et al. 2008). The World Bank Group defines index insurance as "a method of insurance provision that pays out benefits based on a predetermined index that strongly correlates with loss of assets and

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[2] https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html.
[3] http://www.fao.org/3/a-i5402e.pdf.

investments resulting from weather and catastrophic events, without requiring the traditional services of insurance claims assessors."[4] Historical hazard and inventory damage data are used in the design of index insurance products, which trigger pay-outs at specific frequency and severity levels.[5] Thus, index insurance makes the claims settlement process quicker and more objective. These characteristics help address some of the constraints in the offering of agricultural insurance, as the product can be made more affordable and effective for smallholder farmers, while also being commercially viable for insurance companies.

The potential for better uptake makes well-designed index insurance products easier to commercialize, and an easier case for reinsurance access in developing countries (Carter et al. 2014). Index insurance has been piloted in around 15 developing countries at the individual farmer level, while around 20 countries have offered it at an institutional/geographic level (Carter, Janvry, et al. 2017).

Despite the success of index insurance at the pilot level, countries have struggled to enjoy its sustained benefits – for several reasons. One of them is basis risk. Basis risk results from discrepancies between the measured insurance index and the losses actually experienced from adverse events by the insured, i.e. "imperfect correlation between the insurance index and the shocks that it is meant to protect against" (Carter, de Janvry et al, 2017).[6]

Rainfall has been the most commonly used trigger for weather-based index insurance. In case of rainfall indices, product design can be further complicated by the existence of other sources of water for cultivation, such as irrigation. Hydrological drought is a result of the reduction in water supply in rivers, streams and groundwater due to rainfall deficits.[7] In times of hydrological drought, farmers face the risk of limited water supply leading to a 'water supply gap' that may have negative effects such as increasing production cost or crop failure. However, agricultural insurance coverage against such hydrological drought is limited due to its systemic character, where large losses over vast areas can be experienced (Pérez and Gómez 2014).

Given the increasing dependence on irrigation in agriculture, developing robust insurance products for hydrological droughts has evinced increased interest. Though the existing literature and experience are

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[4] https://olc.worldbank.org/content/introduction-index-insurance.
[5] For useful technical guidance on index product design, please refer 'Risk Modeling for Appraising Named Peril Index Insurance Products: A Guide for Practitioners' by Mapfumo, Hybert & Dugger (2017).
[6] Index Insurance for Developing Country Agriculture: A Reassessment (Michael Carter, Alain de Janvry, Elisabeth Sadoulet, Alexandros Sarris Annual Review of Resource Economics 2017 9:1, 421-438).
[7] It emanates from a meteorological drought which is the lack of precipitation over a large area and for an extensive time period. Meteorological drought combined with high evaporation rates can lead to reduced soil moisture and thus agriculture drought, where soil moisture is insufficient to support crops. Subsequent groundwater recharge and reduced streamflow lead to hydrological drought (Tallaksen & van Lanen 2004).

limited, several researchers have begun studying the use of both indemnity and index insurance to manage hydrological drought risks. Leiva and Skees (2008) were one of the first to present a hydrological drought index-based insurance product in Mexico, considering ‘inflow accumulation’[8] as the trigger. Ruiz et al. (2015) proposed indemnity insurance to cover the risk of hydrological drought in irrigated agriculture.

Maestro et al. (2016) proposed an index-based insurance scheme in Spain, covering the risk of water supply failure in irrigation districts, taking ‘stock of water available in reservoirs’ as the trigger. The authors also identified a need to restrict the insurance period strictly between September and May of any given year. This is because reservoir basins in southern Spain, as well as in the Mediterranean and semiarid developed countries, have a large water storage capacity compared to annual inflows and annual water demands. Thus, hydrological droughts occur only after an extended stretch of meteorological drought (normally longer than a year), leaving room for an adverse selection of insurance. In contrast, in the case of Sri Lanka, the probability of hydrological drought occurring within the same year as a meteorological drought is higher. Maestro et al. (2016) also advise that additional studies should be carried out from the supply side prior to commercialization. They have extended this analysis in another paper covering California.

Most recently, Guerrero-Baena and Gómez-Limón (2019) too proposed a method for insuring water supply in irrigated agriculture using an index based on the stock of water available in reservoirs as an optional solution to address hydrological drought.

2. Objective of This Study

This study presents the experience of designing an innovative index insurance product that considers rainfall as well as irrigation water availability, to improve product accuracy in paddy farming in Sri Lanka. The paper presents a product where an index primarily based on a meteorological drought trigger has been improved upon for basis risk by introducing a secondary trigger relating to hydrological drought.

[8] As per the paper by Leiva and Skees (2008), river flows/ inflows, refer to the volume of water that flows into a reservoir in a given period of time. Leiva and Skees (2008) focus on the accumulated volume of these river flows over a specific period rather than the actual rate of the flow.

3. Agriculture in Sri Lanka

Sri Lanka's agricultural history dates back more than 2,500 years. For centuries, paddy cultivation[9] in the island nation was not just an economic activity but a way of life that shaped society, culture, and religion. Agro-climatically, Sri Lanka has an unusually favorable environment for the exploitation of rainfall and cultivable land through irrigation,[10] given the wide range of climatic and soil conditions conducive to growing rice. Rice is grown year-round, as the country enjoys two cropping seasons linked to the two monsoons with rainfall, ground elevation and temperature all conducive for paddy.[11] Even today, agriculture accounts for 26 percent of employment[12] in the country.

Given the important role agriculture has played in Sri Lankan society, it is not surprising that the supply of water for agriculture has been a focus since ancient times, leading to advanced developments in water resources management/hydraulic irrigation. Sri Lanka had some of the most complex irrigation systems of the ancient world, and many of these tanks and canals are still functional. For example, King Pandukabhaya (reigning from 437 to 367 BC) constructed one of the earliest irrigation tanks called Basawakkulama. Tanks like Tissa Wewa and Nuwara Wewa were first constructed around 200 BC and are a major source of irrigation in the Anuradhapura district even today.

As of 2017, approximately 790,000 hectares of paddy land was being cultivated of which 75 percent was irrigated. Cropping intensity in irrigated areas is about 150 percent, compared to rainfed areas where it is 100 percent. About 400,000 hectares fall under major irrigation schemes,[13] with 100,000 hectares under the Mahaweli irrigation scheme[14] and a further 300,000 hectares collectively managed - through about 300 small schemes - by the Irrigation Department of the government.[15]

Many of the larger tanks are interconnected and feed a smaller network of canals. An additional 200,000 hectares fall under minor irrigation schemes (below 80 hectares each), managed by the Department of

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[9] Rice, the staple food in Sri Lanka, is grown in paddy fields. A paddy field is a flooded parcel of arable land used for growing semiaquatic rice.
(http://www.statistics.gov.lk/agriculture/Paddy%20Statistics/PaddyStats.htm)

[10] http://www.ips.lk/irrigation-and-agriculture-in-sri-lanka/.

[11] http://www.fao.org/3/x6905e/x6905e0c.htm;
https://www.doa.gov.lk/rrdi/index.php?option=com_sppagebuilder&view=page&id=42&lang=en.

[12] Annual Bulletin, Labor Force Survey Sri Lanka (2017).

[13] Major schemes have a command area of more than 600 ha. Minor schemes have a command area of less than 80 ha. Medium schemes have a command area of between 80 ha to 600 ha (North Western Province Water Resources Development Project In Sri Lanka, 2004).

[14] Based on discussions with Mahaweli Authority of Sri Lanka, Ministry of Mahaweli Development and Environment.

[15] Irrigation sector in Sri Lanka: Recent Investment Trends and the Development Path Ahead, IWMI.

Agrarian Services. There are about 15,000 such minor schemes, with about 50 percent of them currently operational.[16]

Rainfed agriculture in Sri Lanka is still very prominent, with approximately two-thirds of crop cultivation being rainfed farming. The mean annual rainfall is approximately 1,900 mm. Rice farming is mostly irrigated, but about a third of rice production is still rainfall dependent. Most rainfall-dependent farming occurs in the Maha season (September to March) during the north-east monsoons. Farming during the Yala season (May to August) mostly uses irrigation. Rice is cultivated at an annual average of 870,000 hectares, with 560,000 hectares during the Maha season and 310,000 during the Yala season.[17]

Rainfall-dependent farming is exposed to various risks, such as changes in the seasonal rainfall pattern, dry spells, lower number of rainy days, late onset of the season, high intensity of rainfall, droughts in the dry zone areas, and also rain-triggered flash flooding.[18]

4. Development of Index Insurance for Sri Lanka

One of Sri Lanka's first experiences in index insurance for agriculture was a pilot for the tea sector by SANASA Insurance Company with technical assistance from the International Finance Corporation (IFC) in 2011-2014. The pilot was for smallholder tea farmers in Ratnapura district who relied entirely on rainfall as the source of water for their cultivation. This was an opportunity to experiment with an index insurance product based on rainfall data, which has been popularly deployed in other parts of the world. This pilot resulted in a commercially successful product with positive correlation to the farmers' actual experience. The main prerequisite for the pilot was a reliable source of rainfall data.

[16] http://www.ips.lk/irrigation-and-agriculture-in-sri-lanka/.
[17] http://doa.gov.lk/rrdi/index.php/en/crop/42-crop-rice-cultivation.
[18] Institutionalizing Agricultural Water Management at Local Level in Sri Lanka, Mrs. K.R.S. Perera, Ministry of Agriculture Development & Agrarian Services.

Building on this experience, the IFC has been providing technical expertise to the Agricultural and Agrarian Insurance Board (AAIB) of Sri Lanka since 2017 to expand the index insurance coverage to paddy as well. Given that rice is the staple food in Sri Lanka, its source - the paddy crop - is the main and biggest cultivation in the country, with approximately 1.8 million farm families engaged in its cultivation. About 2.7 million tonnes of rough rice are produced annually, which meet 95 percent of the domestic requirement. Rice provides 45 percent of the total calorie and 40 percent of the total protein requirement of the average Sri Lankan.[19]

Box 1: Institutional framework

Key institutions managing the national irrigation schemes are:

- Irrigation Department
- Irrigation Management Division
- Mahaweli Authority
- Department of Agrarian Services
- Water Resources Board
- Ministry of Agriculture

These institutions were crucial in providing the needed historical and live irrigation data to design and monitor the payouts of the index insurance product piloted in 2018.

A significant part of the cultivable paddy land relies on irrigation. Given this context, using an index insurance product based solely on rainfall posed challenges and led to higher basis risk. Thus, the project explored innovative approaches to adapt the index insurance product to suit the local context, incorporating irrigation.

The process was a complex one, as neither irrigation nor rainfall could be included in the index in isolation. Both variables had an interplay in the crop. The need was to design a suitable index insurance product which combined both variables. Such index insurance products based on irrigation water availability coupled with rainfall are an innovation in this space.

5. Characteristics of the Pilot Locations

The relevance of irrigation varies by region throughout the country. This project was carried out in two districts, Vavuniya and Anuradhapura (refer to the map in Annex 1). Vavuniya is a district in the dry zone, more dependent on rainfall – only two of its eight Agrarian Service Centres[20] (ASCs) have access to irrigation from the only available major tank in the area, Pavatkulam, with a catchment area of less than 30,000 hectares.

[19] http://doa.gov.lk/rrdi/index.php/en/crop/42-crop-rice-cultivation.

[20] Agrarian Service Centers (ASCs) are a network of offices under the Department of Agrarian Development of the Ministry of Agriculture of Sri Lanka, which handles all administrative and institutional matters related to agriculture development across the country, totaling approximately 550 centers.

In contrast, Anuradhapura is one of the most irrigated agricultural areas in the country, having access to 11 major tanks and receiving water from the country's main irrigation system – Mahaweli – as well. In both districts, some farmers have access to water from the irrigation system, making it possible for them to cultivate even during a drought.

6. Design of the Index Insurance Product

A farmer in either district, who relies on rainfed or minor irrigation for his/her farming, could be covered through the pure rainfall index insurance product (refer Box 2). This product would reflect the losses suffered by the farmer due to adverse weather conditions.

> *Box 2: Functionality of pure index insurance products*
>
> Index insurance products provide compensation to farmers based on pre-agreed rules and thresholds. For example, if a dry spell is defined as 20 consecutive days with rainfall below normal, a weather index insurance product protecting farmers against dry spells would automatically trigger payouts to the insured farmers if the actual rainfall observed reached this specific trigger over a specified time period. There is no need and usually no scope for farmers to report claims for pure index insurance products. Similarly, there is also no need usually for the insurance company to verify actual losses on the ground, which is usually a very expensive and time-consuming process and often lacks transparency on both sides.

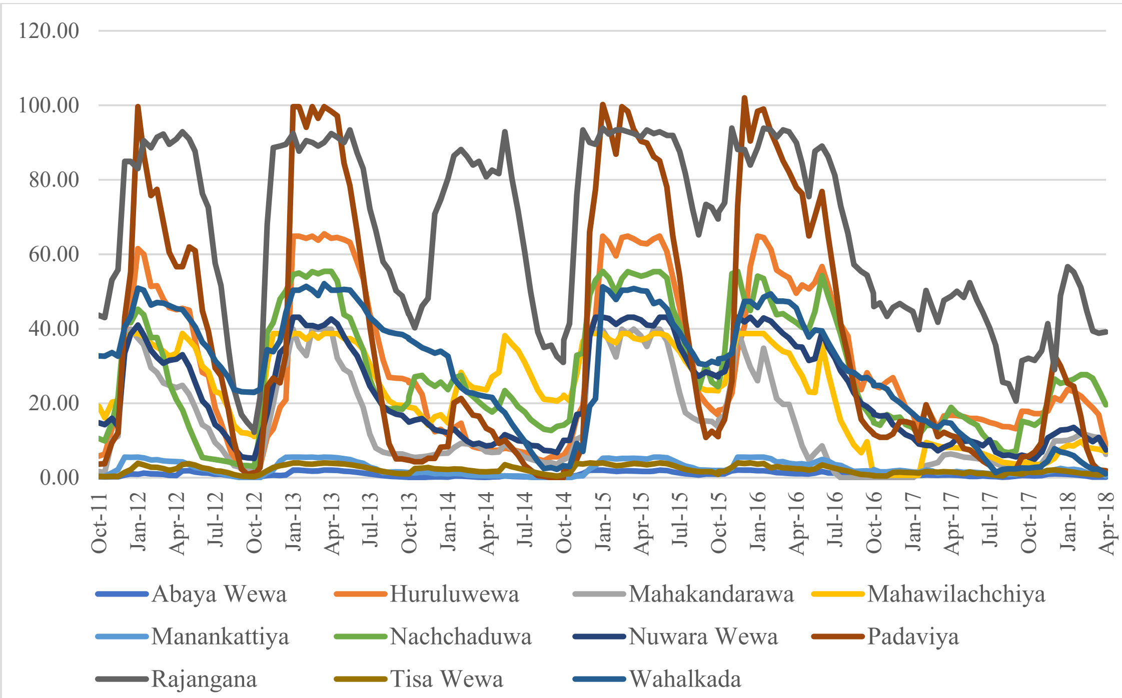
Farmers with access to medium and major irrigation schemes have relatively low-risk exposure to drought and dry spells in comparison to solely rainfall-dependent farmers. The farmer, even if the rainfall is below average, can access water from medium and major tanks. However, such farmers could still face a fall in their profit margins due to the higher cost of production (e.g. cost of operating pumps for irrigation). They can also incur crop losses if there is insufficient water in the tanks for irrigation.

While small tanks and some medium ones rely exclusively on rainfall, the major ones are fed by both rain from different catchment areas as well as major rivers. In Anuradhapura, for instance, rain is not the sole source of water for the tanks. While developing index insurance products in such situations, it is thus very important to consider the type of water supply to each farm in terms of rainfall dependency as well as access to minor, medium and major irrigation channels.

Given that minor tanks are solely rainfed, their storage levels in Anuradhapura district vary significantly from the major tanks whose source of water is different.

However, there is positive correlation between tanks of a similar type within the district. The tank levels also follow a seasonal cycle every year, which is closely correlated to the rainfall in the district and also to rainfall in surrounding districts. Analyses of historical tank storage data and historical rainfall data in the districts of Anuradhapura and Vavuniya show correlations of 0.4 to 0.7 between tank storage level and rainfall on a monthly basis. The tank storage levels also show the general trend of the rainy seasons. For example, monthly average storage levels from the Nuwara Wewa tank in Anuradhapura show that storage levels increase with the rains starting in November-December, peak in January, and stay stable until June before sharply declining over July to October[21] due to the lack of rain during these months. Tank water levels are managed by the relevant institutions (Refer Box 1) to ensure sufficient water supply to farmers via the irrigation network. Historical tank storage data in million cubic meters (MCM) for the 11 major tanks in Anuradhapura district are shown in Figure 1.[22]

Figure 1. Historical Tank Effective Storage (MCM) for Major Tanks in Anuradhapura District



Source: Author-constructed based on MCM data from Irrigation Department of Sri Lanka.

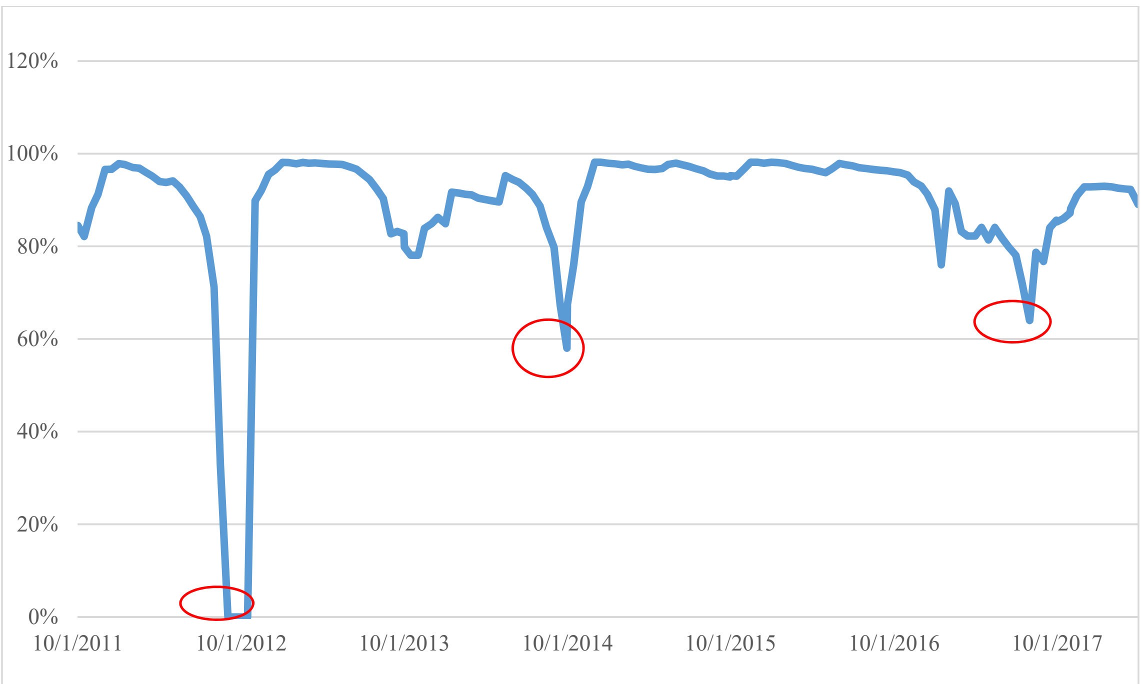
While rainfall and water available for irrigation are positively correlated as expected, their correlation is not all that high due to other factors that affect the water tank level – such as inflows from canals and tanks in other regions. This implies that rainfall on its own cannot be a very good proxy of tank storage level, and thereby the water available for irrigation.

The other important aspect is the correlation between tank storage levels and crop yields/losses. Data from three Yala seasons in Vavuniya showed a strong negative correlation of -0.93 between the

[21] Irrigation Department, Ministry of Irrigation and Water Resources Management, Sri Lanka.
[22] Irrigation Department, Ministry of Irrigation and Water Resources Management, Sri Lanka.

effective storage level of the tank (Pavatkulam) and the damage ratio for paddy during those periods. This implies that when the effective storage level of the tank reduces, it is very likely to reduce crop yield and increase the damage incurred in that season. In the 2012 and 2014 Yala seasons, for example, the average effective storage level (from June 1 to September 30) was very low at 23 percent and 54 percent respectively of the average normal level for the same time period (which is 9.54 MCM, based on data over 2012 to 2017). The damage ratios for these seasons were at 36 percent in 2012 and 18 percent in 2014, indicating a strong negative correlation. Moreover, in the 2015 Yala season, the effective storage in Pavatkulam tank was almost double (188 percent) the normal storage level for June-September and again the damage ratio was strongly negatively correlated, being only 1 percent, which implies a very good harvest. Hence, storage levels can potentially be used as a good proxy for crop losses due to drought in the Yala season for farmers who have access to water from this tank.[23]

Figure 2. Effective Storage as a % of Gross Storage (MCM) for Pavatkulam Tank in Vavuniya

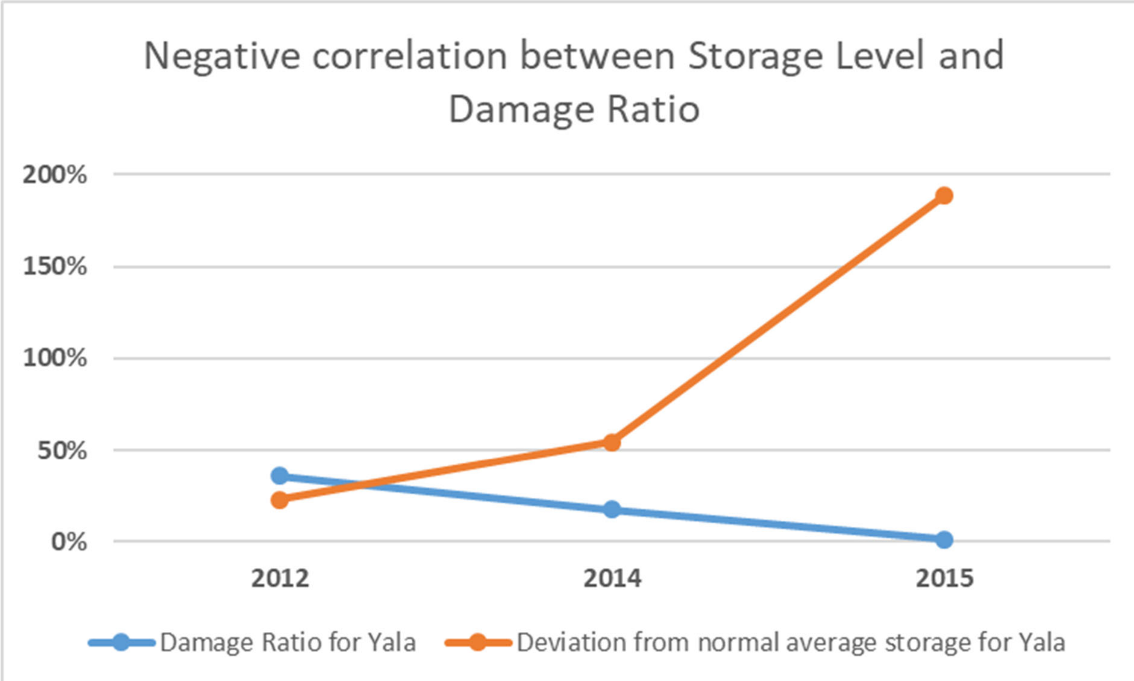


Source: Author constructed based on MCM data from Irrigation Department of Sri Lanka.

Figure 3 shows the strong negative correlation between the average effective storage level (during the Yala season) and the damage ratio for the Yala season in Vavuniya over three seasons for which comparable data are available.

[23] Irrigation Department, Ministry of Irrigation and Water Resources Management, Sri Lanka.

Figure 3



Source: Author constructed based on data from Irrigation Department and Ministry of Agriculture of Sri Lanka

Comparing historical tank storage levels with rainfall, crop yield, and production loss data, it was seen that tank storage levels can be effectively used as a verification trigger for the purpose of claims, i.e., when the storage levels are low, there is a high probability of a lower yield. However, for the actual calculation of the claim amounts, it may be difficult to rely solely on tank storage levels, due to the significant concentration risk or the geographical aggregation of the risk. Hence, it is advisable to use tank storage data to determine whether farmers had access to sufficient water from irrigation or not.

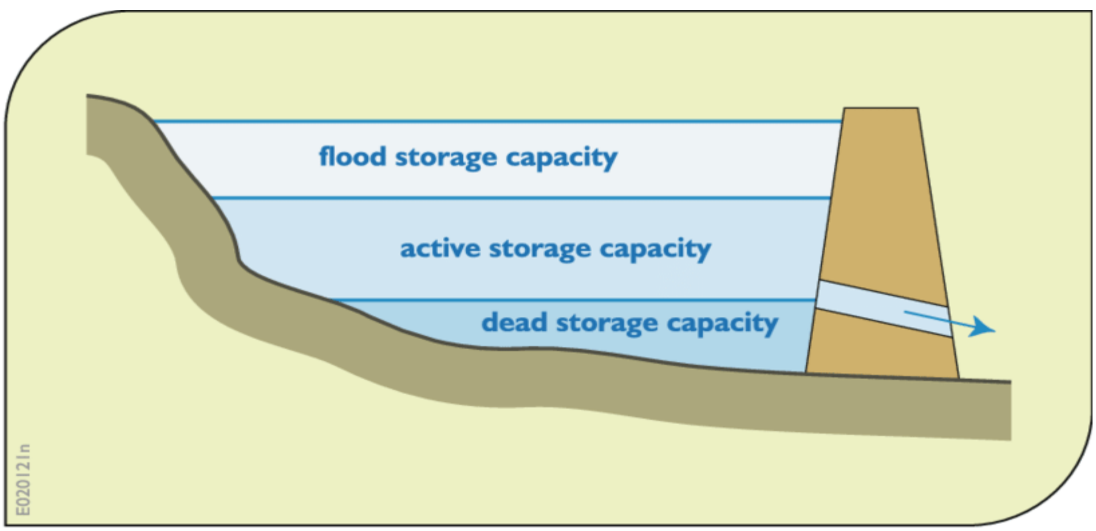
Sri Lanka has more experience of hydrological drought occurring in the same year as a meteorological drought, compared to, say, Spain (Maestro et al, 2016). Even so, to avoid adverse selection (since farmers can foresee a hydrological drought at sowing time), the product is designed such that a pre-determined date is set as the last date on which insurance can be purchased for the season.

As an example of the geographical aggregation of risk, in Anuradhapura district, the Abaya Wewa tank is strongly positively correlated to the other 10 major tanks in the district, with correlations varying between 0.66 and 0.90. Similar high correlations exist among the other major tanks in Anuradhapura as well. Thus, there is strong probability of most of the 11 major tanks in Anuradhapura triggering a pay-out in the same season if storage level alone is used as the primary and sole basis for the index insurance product. The lack of geographical diversification of the irrigation related risk would make it very difficult to insure/reinsure such a risk and would also make the insurance product very expensive.

Hence implementing an index insurance product purely based on tank storage level alone is not recommended. However, if an additional granular index is used, such as a rainfall index based on localized weather stations or rainfall gauges, the concentration risk can be much reduced. The risk would be reduced because, while tank storage level can be used to determine whether a pay-out is eligible or not, the actual size of the pay-out can be determined by the second, more granular index, such as that of rainfall or yield. Thus, the claims' frequency would be determined by a combination of the tanks' storage levels and the second parameter (e.g. rainfall), but the claims severity (size) would depend upon rainfall data only. Such an approach would reduce the geographical concentration risk associated with basing pay-outs on tank storage levels only. Hence, it is important to use the storage level together with other indices such as those of rainfall or yield, at a localized level.

When measuring tank levels, the parameter applicable to the index product is the effective storage capacity. The effective (or active) storage capacity of a reservoir is defined as the total usable reservoir capacity. It is the level above the dead storage capacity, which is the inactive storage that cannot be drained by gravity, as illustrated in Figure 4 below.[24]

Figure 4.



Source: River Basin Modelling, Pete Loucks, Cornell University

[24] River Basin Modelling, pp. 469-526, Water Resource Systems Planning and Management, March 2017, Pete Loucks, Cornell University.

Hence, the effective storage is the gross storage minus the dead storage. It can be calculated from the following formula:

Effective Storage (MCM) = MAX{Gross Storage (MCM) – Dead Storage (MCM),0}

To construct the index, the effective storage from the relevant major tanks is recorded on the 1st and 15th of every month from November to March to cover the Maha season. The normal monthly effective storage levels are specified for each tank. (The storage level data is also available on a daily basis for some tanks.) For example, for Pavatkulam tank in Vavuniya, the normal monthly effective storage levels, based on seven years of recorded data from 2011 to 2017, are as follows:

Table 1. Normal Monthly Effective Storage Levels – Pavatkulam Tank

Month	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Effective storage (MCM)	9	16	19	17	14

Source: Author constructed, based on MCM data from Irrigation Department of Sri Lanka.

The effective storage level of major tanks can be used as a parameter for more accurately identifying yield stress for farmers with access to irrigation from them. The indexed pay-outs would then only take place in a situation where adverse weather conditions have occurred while tank storage levels were also low in the same season. For example, if the actual average monthly effective storage level is less than a threshold level (e.g. less than 90 percent of the normal monthly effective storage level) that month can be considered a 'low tank level' month. Depending on the crop and its reliance on irrigation, it is possible to estimate how many such 'low tank level' months will result in crop yield stress. The indexed pay-outs can be structured accordingly.

The table below sets out different scenarios, noting which ones would lead to pay-outs and which would not, using both the number of 'low tank level' months and the rainfall index.

Column A represents the number of months (over November to March) during which the average monthly effective storage level is below a specified threshold (i.e. the number of Low Tank level months).

Column B represents whether a dry spell event has been triggered (or not) based on the rainfall conditions as measured by weather stations or rainfall gauges. Typically, dry spell events are for deficient rainfall over a specified number of consecutive days (e.g. cumulatively 'low' rainfall over 20 consecutive days for an early dry spell).

Column C represents whether an excessive rainfall event has been triggered (or not) based on the rainfall conditions as measured by weather stations or rainfall gauges. Typically, excess rainfall events occur for excessive rainfall over a specified number of consecutive days (e.g. over 3 consecutive days).

Column D represents the resultant pay-out, which is contingent on the combination of the previous three indices.

Table 2. Pay-out Scenarios

Column A	Column B	Column C	Column D
Number of Low Tank Level months (e.g. over November to March)	Dry spell trigger (as per rainfall trigger for dry spell)	Excess rainfall trigger (as per rainfall trigger for excess rainfall)	Total Indexed Pay-out
Less than 3	No	No	No pay-out
Less than 3	Yes	No	No pay-out
Less than 3	No	Yes	Excess rainfall pay-out only
Less than 3	Yes	Yes	Excess rainfall pay-out only
3 or more	No	No	No pay-out
3 or more	Yes	No	Dry spell pay-out only
3 or more	No	Yes	Excess rainfall pay-out only
3 or more	Yes	Yes	Dry spell pay-out plus excess rainfall pay-out

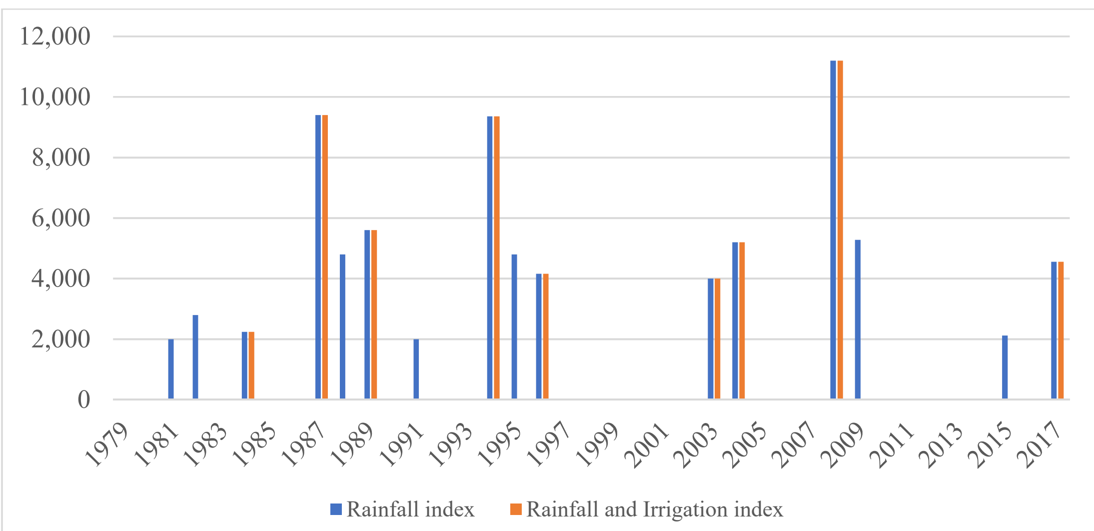
As per the scenarios tabulated above, pay-outs for dry spells are made only when both the rainfall and the tank storage levels fall sufficiently below their respective trigger levels. However, excess rainfall pay-outs are independent of tank storage levels. These are triggered purely on the basis of the rainfall.

7. Performance

The product is expected to be piloted in the next season – the Yala season (May - Sep 2019), which depends more heavily on irrigation. To improve its efficacy, it is important to track its performance in terms of pay-outs and compare these pay-outs to the actual experience of farmers in terms of production losses and reasons for those losses for at least two years. It is also important to use additional historical storage data, if possible, and to complement the dataset with other sources of data, including satellite data sources.

Based on the actual rainfall and irrigation tank level data[25] in Anuradhapura, Figure 5 below presents simulated historical pay-outs. For the Maha season, the years of 2003, 2004, 2008 and 2017 were particularly bad years, when crop losses were incurred due to dry spells. The simulated pay-outs show that the pure rainfall index insurance product (blue bars) would have triggered pay-outs in all these years. However, it would have also triggered pay-outs in other years, such as 1995, 2009 and 2015, when pay-outs would not have been necessary for farmers with access to major irrigation. Hence, a pure rainfall index product would have triggered more pay-outs than necessary, leading to a more expensive product and not addressing the lower risk profile of irrigated farming. Used together, the rainfall and irrigation index (red bars) would have triggered pay-outs only in the particularly bad years, which would be a more relevant and affordable product for farmers with access to major irrigation.

Figure 5. Product Simulated Pay-outs for Anuradhapura (in LKR)

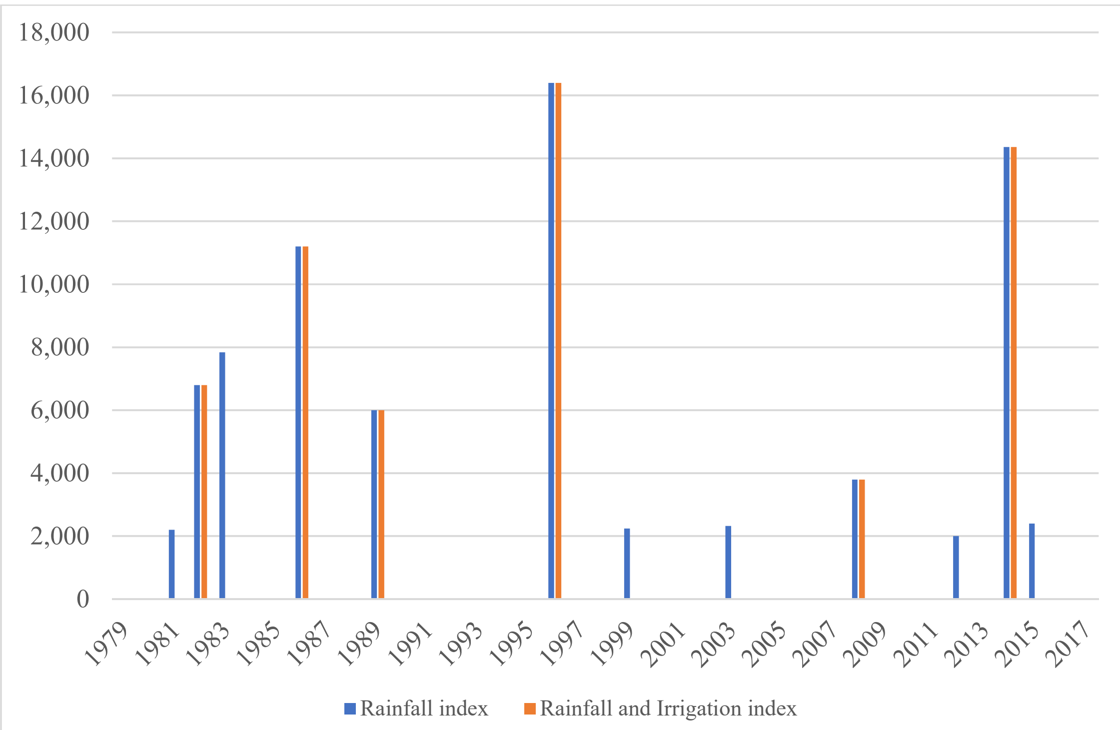


Source: Author-constructed based on meteorological data (Meteorological Department of Sri Lanka) and MCM data (Irrigation Department of Sri Lanka).

[25] Based on Huruluwewa tank, from Irrigation Department, Ministry of Irrigation and Water Resources Management, Sri Lanka.

Figure 6 presents a similar exercise for Vavuniya, based on actual rainfall and irrigation tank level data.[26] For the Maha season, the years 1996, 2008 and 2014 were particularly bad, when crop losses were incurred due to dry spells. The simulated pay-outs (blue bars) show that the pure rainfall index insurance product would have triggered pay-outs in all these years. However, it would have also triggered pay-outs in years such as 2003, 2012 and 2015, when pay-outs would not have been necessary for farmers with access to major irrigation. Once again, a pure rainfall index product would have triggered more pay-outs than necessary, leading to a more expensive product and not addressing the lower risk profile of irrigated farming. The rainfall and irrigation index (red bars) would have triggered pay-outs only in the specific bad years, which would be a more relevant product for major irrigated farms as well as lead to a lower premium.

Figure 6. Product Simulated Pay-outs for Vavuniya (in LKR)



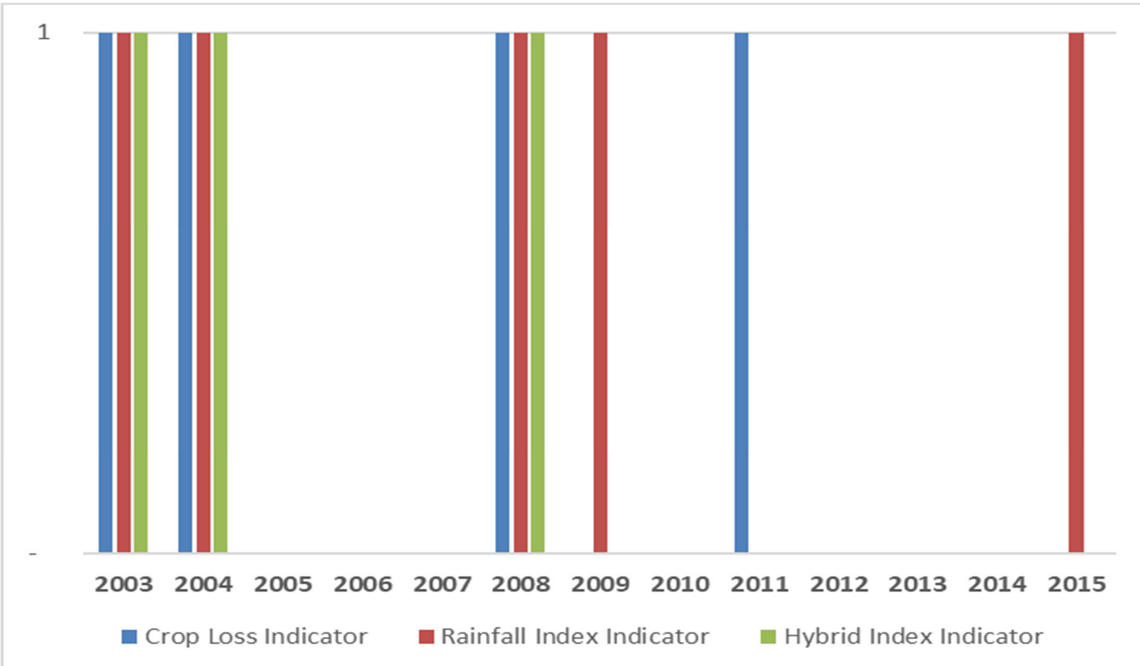
Source: Author constructed based on Meteorological data (Meteorological Department of Sri Lanka) and MCM data (Irrigation Department of Sri Lanka).

Based on information collected on damages for the Maha season in Anuradhapura through focus group discussions with farmers, it has been established that severe crop losses occurred in the district in the Maha seasons of 2003, 2004, 2008 and 2011. This was also validated by an analysis of damage ratios.

[26] Based on Pavatkulam tank, from Irrigation Department, Ministry of Irrigation and Water Resources Management, Sri Lanka.

The hybrid index matches these historical losses more closely than the pure rainfall index. The graph below shows the incidence of yield losses and pay-outs for the rainfall index and hybrid index based on binary indicators.

Figure 7. Yield Losses and Pay-outs for the Rainfall Index and the Hybrid Index



Source: Author constructed based on Meteorological data (Meteorological Department of Sri Lanka), MCM data (Irrigation Department of Sri Lanka) and farmer focus group discussions.

The comparison shows that the pure rainfall index would have resulted in pay-outs in some seasons (such as 2009 and 2015) which did not correspond to significant crop yield losses. The correlation between the incidence of losses and the pure rainfall index is only 0.51, whereas the correlation between the incidence of losses and the hybrid index is 0.82. It is clear that the hybrid index (rainfall and irrigation) product results in a better correlation with the losses incurred by farmers with access to major irrigation. The hybrid index product is also cheaper due to pay-outs occurring only when there is low rainfall as well as low irrigation tank water levels. It more accurately reflects the lower risk of farmers with access to major irrigation.

The product also reduces the basis risk for both farmers as well as the insurance (and reinsurance) companies by reducing cases when farmers did not suffer losses but could still receive pay-outs. For example, as per the above graph, with the rainfall index, farmers would have received pay-outs in 2009 and 2015 Maha seasons, even though they do not seem to have suffered significant losses in those seasons. The hybrid index, however, would take the above normal tank water levels in those seasons into account and there would have been no pay-outs in those years, leading to a cheaper product and one which is also a better fit to the farmers' actual yield losses, apart from making them more insurable from the insurance companies' perspective.

To further compare the relative accuracy of the rainfall index and the hybrid index (rainfall and irrigation) products, a correlation analysis of the aggregated loss data (as obtained from the district damage ratios and supplemented with loss data using feedback from farmers) was carried out. Losses and insurance pay-outs were simulated stochastically, based on historical rainfall, tank storage, and crop loss data. Correlation analyses were carried out between the levels of simulated losses and simulated pay-outs for the two different types of indices. For losses, both the incidence of losses (using a binary indicator) and the extent of losses (using a Gamma distribution) were correlated to the incidence of pay-outs (using a binary indicator) and the extent of pay-outs (based on the index structure).

Table 3. Summary of Correlations for Vavuniya

	Correlation of incidence of losses and occurrence of pay-outs	Correlation of extent of losses and extent of pay-outs
Rainfall index	57%	49%
Hybrid index (Rainfall + Irrigation)	76%	64%

Table 4: Summary of Correlations for Anuradhapura

	Correlation of incidence of losses and occurrence of pay-outs	Correlation of extent of losses and extent of pay-outs
Rainfall index	58%	52%
Hybrid index (Rainfall + Irrigation)	81%	69%

The correlation analyses indicate that the hybrid index performs better than the rainfall index for farmers with access to major irrigation. The hybrid index performs particularly better at detecting the incidence of losses, which is natural since significant crop losses occur only when both rainfall is low and water available for irrigation is inadequate. The correlations are generally weaker when considering the extent of losses, which is also understandable since the extent of losses also depends on other factors, such as access to water from the tanks, soil types, planting dates, etc. The correlations for the hybrid index are stronger in Anuradhapura district compared to Vavuniya due to the larger number of major irrigation tanks in Anuradhapura.

To test the accuracy of the indices further, a Pearson Chi-square goodness of fit test can also be carried out, comparing the Observed Losses (Oi) to the Expected Losses (Ei) based on the two different types of indices.

Based on this test $\chi_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}$ the following p-values are obtained for the two indices when comparing the observed losses (Oi) and the simulated pay-outs (Ei).

Table 5: Test Results

	p-value for Chi-squared test
Rainfall index	0.046
Hybrid index (Rainfall + Irrigation)	0.033

The lower p-value for the hybrid index indicates that the accuracy of the hybrid index is higher than that of the rainfall index.

The hybrid index leads to pay-outs due to drought (or severe dry spells) being triggered only in those seasons when the rainfall is significantly low and tank storage levels are also significantly low. This feature of the hybrid product leads to a more accurate recording of dry seasons when crop yields of farmers with access to major irrigation is stressed due to the simultaneous occurrence of rainfall deficit and insufficient availability of water from irrigation sources. Hence, the hybrid index leads to a more accurate fit to the actual occurrences of crop yield losses for farmers with access to major irrigation.

In addition, the hybrid index can also lead to a higher claim pay-out amount (compared to a pure rainfall index) because the rainfall triggers can be made more lenient for a hybrid structure since the frequency of pay-outs is lower for a hybrid index insurance product. The pay-outs would be fewer but of larger size in the seasons when they are triggered. In particularly 'bad' seasons, the hybrid index would result in higher pay-outs compared to a pure rainfall index.

Hence, a combination of lower basis risk, stronger correlation (of incidence and extent of loss) and goodness of fit test indicates that the hybrid index (rainfall and irrigation tank storage level) is a more accurate one than a pure rainfall index - though only for farmers with access to irrigation from major tanks.

8. Limitations

The initial pilot product is developed only for the paddy crop. Given the microclimatic conditions in Sri Lanka, it ideally needs to be used over small geographic areas. Additionally, a single product is applicable for a single crop in a season, for a given district – necessitating the development of multiple products as needed.

An issue faced in general for index insurance and particularly for a hybrid product, is the high dependence on several sources of data where limitations in data infrastructure hinder robust product development. For an index based on rainfall, reliable historical rainfall data and a continuous supply of contemporary data are needed to measure product performance. Apart from rainfall, the hybrid product will need tank level data, which, for example in Sri Lanka are usually from several sources, given that the tanks could be managed either by regional level bodies or national level ones.

The hybrid index product addresses negative basis risk associated with irrigated farmlands only to an extent. It is no doubt an improvement on the rainfall index. However, there still remains a residual negative basis risk for irrigated farmlands due to factors like their distance from the tanks – some may be very far away, some very close, and this affects their relative benefits from the tanks. Due to the lack of granular data on individual farm distances from tanks, along with other variables, the impact of such risk cannot be incorporated. Ongoing pilot efforts by IFC in digitization of data, may provide an opportunity to cluster farms in different groups, i.e. by specific irrigation types, their distances from tanks, etc. Once such information is available, the product can be modified to capture these additional parameters, which can further contribute to reducing negative basis risk.

Another limitation of the model itself is that storage capacity can be affected by factors such as a build-up of sediment, tampering with the irrigation infrastructure by external parties, etc. These operational limitations exist, but they can be mitigated to some extent by the structuring of the product. It could be designed using tank storage level as the relevant parameter and not the discharge level. Further, the trigger level of the storage capacity can be set in a way that makes it difficult to manipulate externally, and to take the effect of sedimentation into account. Also, the deviation from the 'normal' storage level for a specific period can be considered, instead of absolute storage levels. So, regardless of the amount of water discharged (which can be affected by water management decisions and negligence), there is a strong probability that drought has taken place if, for instance, the tank's effective storage is found to be low. In districts with multiple tanks (e.g. Anuradhapura) it could also be made possible to use the levels of nearby major tanks as a countercheck if suspicious fluctuation in a particular tank's storage level is noticed. The tank water level will be a contingency check on whether a claim pay-out is eligible or not, but the actual calculation of the pay-out can be based on the rainfall levels.

Further, the product design captures damage from excessive rainfall independent of tank storage levels. Excessive rainfall invariably leads to crop damage, particularly in the crop flowering stage. It can also lead to flash-flooding and waterlogging. However, if localized flood data are available, there is scope to further refine the product by carrying out a multivariate correlation analysis between excess rainfall, flooding and tank storage levels. Such a study may show that the risks of excess rainfall affect irrigated and non-irrigated farmlands differently, since flash-floods are caused by inundation in tanks (from which non-irrigated lands would be immune). However, in the absence of localized flood data currently, no such conclusion can be drawn. Thus, the excess rainfall cover for the product has been structured independent of tank water levels.

9. Conclusion

This paper captures the pilot experience of developing a weather index insurance product for irrigated agriculture in Sri Lanka, from a practitioner's perspective. Our experience has shown that incorporating irrigation water levels contributes to an improved 'hybrid' index insurance product, thereby expanding the use of rainfall index insurance even to irrigated farmlands.

The results of the pilots in two districts show that the hybrid index product is better correlated to crop damage than the pure rainfall index for farmers with access to major irrigation. It is especially better at detecting the incidence and severity of actual losses.

It is important to acknowledge that there may be other types of indices (that may also improve correlation) which can be used in combination with tank storage levels, such as a yield index and a vegetative index in particular contexts, and their relevance in terms of costs and benefits can be compared.

While the pilot exercise was limited to a few seasons and regions, and the experience is too recent to draw general conclusions about the sustainable performance of the hybrid weather index insurance product, the experience so far in Sri Lanka suggests that index insurance can be successfully used in irrigation contexts with relevant improvements in product design, and the product is a value proposition for smallholder farmers in Sri Lanka.

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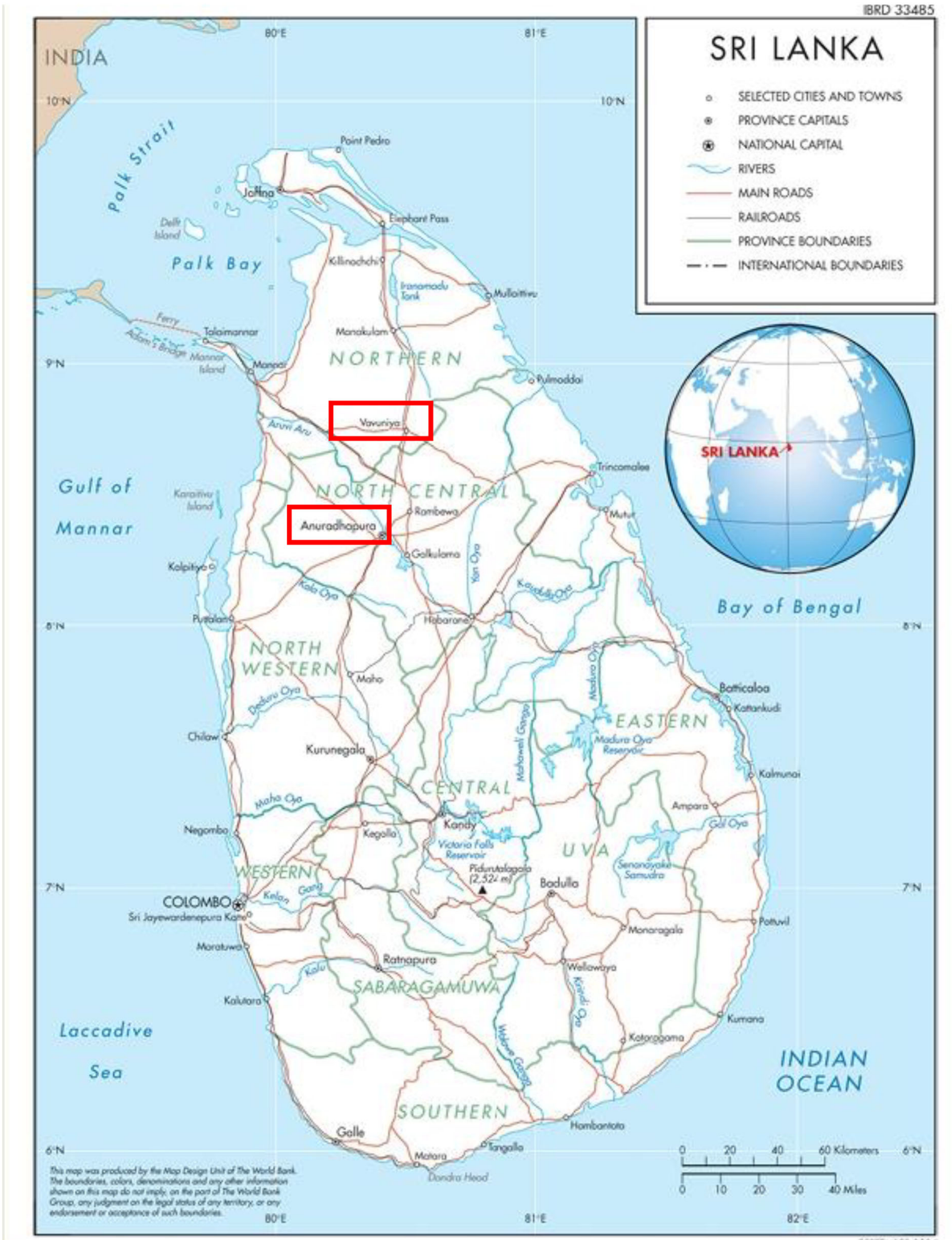
ANNEX 1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Bay of Bengal
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