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*Full Length Research Paper*

# Technical efficiency of vegetable development programs in Kerala, India

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**The paper introduces the context of the study by examining the challenges of hidden hunger arising from the overemphasis on protein-carbohydrate dietary sources in the agricultural and food policy of India. In this setting, the vegetable development program (VDP) introduced at the national level to improve household access to vegetables across the states is discussed. Technical efficiencies, scale efficiencies, and productivity growth are presented as the evaluation measures of VDP implemented in the state of Kerala for the period 2015-2021. Data Envelopment Analysis and the Malmquist productivity index are detailed as the empirical tools of measurement. The results suggest that even though the physical area and capital inputs under VDP recorded an overall reduction in the state over the years, the technical efficiency recorded a steady improvement. More significantly, the observed improvement in technical efficiency reached significant levels in the years of floods (2018-2019) and the COVID-19 lockdown period of 2020-21. This implied the significant contribution of VDP to household vegetable consumption and nutritional security in challenging times. However, a 20 percent increase in overall output was observed as possible by utilising current levels of resources. The results provided more resourceful measures of evaluation protocols for agricultural development programs.**

**Keywords:** Data Envelopment Analysis (DEA), Malmquist productivity index, agricultural development, evaluation measures, nutritional security

## INTRODUCTION

Despite the commendable achievements in crop production, there have been increasing reports of hidden hunger in developing countries like India. Hidden hunger is a form of under nutrition resulting from vitamin and mineral deficiencies related to poor dietary sources that cause health and development problems (Holmer, 2013). The greater the diversity of a diet, the lower the risk of deficiency of essential nutrients, thus diet plays an important role in combating hidden hunger (Lowe, 2021).There are many studies that report the substantial impact food grains had on the calorie and protein intake of the vulnerable sections (Kannan, 1979; Ibrahim and Pramod, 2006; Isaac and Ramkumar, 2010).The predominance of high protein-carbohydrate sources distributed

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through the Public Distribution System (PDS) under food security programs have often been criticized for the rising forms of hidden hunger in the country (George and McKay, 2019). This is because the PDS did not cover vegetables, the best source of minerals and vitamins that protect against all forms of hidden hunger (Dias, 2013, Rahal et al., 2014; Sharma et al., 2017, Harding et al., 2018). Cereal-based diets of people in developing countries may ensure protein sufficiency (though not protein quality), but it does not ensure the adequacy of micronutrients (Bamji et al., 2021).However, the realization has brought the dietary role of horticulture crops, especially vegetables, in combating under-nutrition-related issues to the fore. The role of vegetables needs to be discussed against the irony that the country leads second in the world vegetable production and is also home to about a quarter of the world's undernourished (FAO, 2020). This prevalence of high malnutrition and hidden hunger indicated that food availability alone could not ensure accessibility and nutritional security. The fulfilment of the United Nations Sustainable Development Goal (SDG) targets 2.1 and 2.2 also demands a considerable dietary shift including an increase in the consumption of vegetables (Stadlmayr et al., 2023). It is thus important to ensure year-round access to safe, nutritious, and sufficient food for all people that eradicate all forms of malnutrition (Ridolfi, 2019).Further, it is reported that vegetable production systems, especially homestead systems, showed remarkable resilience by providing much-needed food and nutritional security during the covid 19 pandemic lockdowns to the most vulnerable and those living in fragile social contexts (Serpil and Mehmet, 2020). These brought a shift in targets of food production in India to the horticulture sector, especially fruits and vegetables.

It was against this backdrop, the activities of Vegetable Development Programs (VDP) implemented in major states of India under the National Horticultural Mission assumed significance. VDP increased vegetable production in the country, estimated at 191.77 million metric tonnes from an area of 10.35 million hectares during 2019-20 (PIB, 2020). Each state has unique vegetable schemes under the program that catered to geographical diversity and climatic advantages to ensure the availability of vegetables. It was in this setting that states like Kerala which had high levels of urbanization and standards of living implemented targeted policies to improve the household accessibility of vegetables through area expansion.

It included components of homestead vegetable production, terrace cultivation, grow bag cultivation, and vegetable production through farm clusters facilitated through incentives and irrigation support under the VDP. Also, awareness creation through training and Nutri-garden demonstrations in public institutions like schools, Anganwadi's, etc. were implemented to popularise vegetable cultivation at the household level. The paper examines the technical and scale efficiency of vegetable development programs implemented in the state of Kerala.

## MATERIALS AND METHODS

### Study Area

The study was conducted in Kerala, the southernmost state of India (Figure-1).Conventionally the state relied on the neighbouring states of Tamil Nadu for meeting the dietary requirements of its 340.40 lakh population. In order to meet the dietary requirements as per the ICMR (Indian Council of Medical Research) recommendations of the state's population, 37.27 lakh MT of vegetables are required against the production of 21.57 lakh MT. This implied that 15.70 lakh MT (42.13 %) of the total requirement has been met from external sources. As such, the problems of malnutrition have ever remained a predominant socio-economic issue in the state which was further aggravated by the growing reports of degenerative diseases and cancer. These neighbouring issues have resulted in rising concern about self-reliance and safe-to-eat production standards among consumers (Saleem, 2019; Maryam et al., 2021). This, in turn, has accentuated the need to nurture vegetable production through a combination of supply-side interventions and behavioral change communication aimed at improving internal production. This has resulted in concerted efforts by the State Department of Agricultural Development and Farmers' Welfare (SDOAFW) to improve the quality and productivity of vegetable production.

The implementation of VDP in the state started as early as the 1990s with the Kerala Horticultural Development Program (KHDP) operated under the technical and financial support of the European Union. But it did not cover all districts and remained confined to a few. Mass promotion of vegetable production in the state gained momentum through the implementation of VDP in 2015. The program was implemented as an all-inclusive package that tried to bring vegetable production to both urban and rural households. The major components of the scheme consisted of, the promotion of vegetable cultivation in household clusters, the establishment of demonstration plots in schools and other institutions, the promotion of urban household cultivation in terraces and grow bags, rain shelter cultivation, popularising hybrids and support for irrigation equipment, infrastructure and skill development and awareness programs. Though there have been remarkable investments in the program over the years, efforts were not made to assess the technical and scale efficiency of the scheme which was focussed on in the study.


**Figure 1.** Map showing the study area

## Sampling and Data collection

Purposive sampling of Kerala was based on the consistent importance received by VDP in all 14 districts of the state. Various public agencies involved in the implementation of the program in the state served as the data sources of the study. Accordingly, data were collected from the Farm Information Bureau (FIB), the State Department of Agriculture and Farmer`s Welfare (SDOA), and the Vegetable and Fruits Promotion Council of Kerala (VFPCK) that implemented VDP in the state. Secondary data on the budget allotment and expenditure incurred under the various components of the vegetable development program (VDP) implemented in the state for the period 2015-2021 were collected. Exhaustive sampling was followed to collect data from 941 Grama panchayats and 87 Municipalities (152 Blocks in 14 districts) in the state where the VDP was implemented to get the details of the area covered. The published sources of agricultural census data and the district-wise area under vegetables were also compiled for analysis.
Collected data for seven years (2015-16 to 2000-21) were used to construct the input and output variables. Measures of capital inputs were constructed from the data on annual investment and its use under various components of VDP implemented in the districts. Inputs related to labour and input costs were not selected as there existed a lack of uniformity in implementation protocols and unavailability of published data, exclusively for vegetables. This could be explained in relation to inter-district variations in production situations and heterogeneity of crops included under vegetables. The measure of output selected was the annual area under vegetable cultivation covered under VDP.

## Data Analysis

The study used Data Envelopment Analysis (DEA), the non-parametric mathematical optimization method, to determine the technical, scale efficiency, and total productivity change of VDP over the years. It used linear programming techniques to envelope the observed input-output vectors as tightly as possible. The premise followed in the approach does not place any *apriori* relationship between the production function parameters or the distributional form of the inefficiency component. It provided the advantage of comparing inefficient units with the best-performing ones in a selected group on multiple input-output pioneered by Farell (1957) and evaluates technical inefficiency as the proportional reduction in input use with output levels held constant. The model was preferred as the input use was the primary decision variable over which the program managers had some control. The model assumed that an inefficient unit could become efficient by reducing the input use and retaining the constant output level. As a comparative approach based on optimization, it helped to identify the optimal performance of alternatives rather than averages.

The non-radial model of slacks-based measure of efficiency (SBM) that used specific slacks for each input or output was also adopted (Tone, 2011). In the analysis, each district of the state was considered a Decision-Making Unit (DMU) and was considered technically efficient when the DEA score was one and all slacks (excess inputs) were zero. So, the assumption of constant returns to scale (CRS), which estimates the gross efficiency of a DMU (Charnes et al., 1978; Ramanathan, 2003), and the variable returns to scale (VRS) model that measures pure technical efficiency (Banker, 1984) were used in the analysis. The models represented as (1) and (2) use the following notations: 'n' number of DMUs to be evaluated represented by the 14 districts; each DMU has m inputs related to year-wise investments made under different components of VDP and produces the output taken as the vegetable area covered for the respective years.

The assumption followed was that a $DMU_j$ consumes $x_{ij}$ of input i and produces $y_{rj}$ of output r; $\lambda_j$- the weights assigned by the linear program, Θ- the efficiency calculated; $s_i$ and $s_r$ are the input and output slacks; ϵ - is a non-Archimedean element defined to be smaller than any positive real number (Rita, 2011; Vukeli and Nebojsa, 2013).

The CRS input-orientated programming was based on the following equation (1)

$$\text{Min } \theta + \varepsilon\left[\sum_{i=1}^{m} S_{\bar{i}} + \sum_{r=1}^{s} S_{\underset{r}{+}}\right] \text{-------------------------(1)}$$

Subject to $\sum_{j=1}^{n} x_{ij}\lambda_j + S_{\bar{i}} = \theta x_{i0}, i = 1,2,\ldots,m$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - S_{\underset{r}{+}} = y_{r0}, r = 1,2,\ldots,s$$

$\lambda_j, S_{\bar{i}}, S_{\underset{r}{+}} \geq 0$ j=1, 2, …, n

Whereas the VRS input-orientated programming followed equation (2) as given below

$$Min\theta + \varepsilon\left[\sum_{i=1}^{m} S_{\bar{i}} + \sum_{r=1}^{s} S_{\underset{r}{+}}\right] \text{---------------(2)}$$

Subject to $\sum_{j=1}^{n} x_{ij}\lambda_j + S_{\bar{i}} = \theta x_{i0}, i = 1,2,\ldots,m$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - S_{\underset{r}{+}} = y_{r0}, r = 1,2,\ldots,s$$

$\sum_{j=1}^{n} \lambda_j = 1; \lambda_j, S_{\bar{i}}, S_{\underset{r}{+}} \geq 0$ j=1, 2, …, n

Based on the gross technical efficiency (TE) and the pure technical efficiency score (PTE) scores, the scale efficiency (SE), which reflects the potential area expansion that can be gained by achieving an optimum size of a DMU was calculated as follows (3).

$$SE = \frac{TE}{PTE} \text{-------------------(3)}$$

Malmquist productivity index which evaluates the efficiency change of a DMU between two time periods was also used to analyse the cross-sectional and time series data in the study. The index is defined as the product of "Catch-up" and "Frontier-shift" terms. The catch-up (or recovery) term related to the degree that a DMU attains to improve its efficiency, while the frontier-shift (or innovation) term reflects the change in the efficient frontiers surrounding the DMU between the two time periods (Tone, 2004). The index checked the timelines of change in efficiencies over the period 2015 pioneered to 2021 (Fuentes & Lillo-Bañuls, 2015).

Measurement of productivity change was made relative to period t ($M_0^t$) or relative to period t+1 ($M_0^{t+1}$) (Caves et al 1982a; 1982b), where $M_0^t = \left[\frac{D_0^t\,(X^{t+1},Y^{t+1})}{D_0^t\,(X^t,Y^t)}\right]$ and $M_0^{t+1} = \left[\frac{D_0^{t+1}\,(X^{t+1},Y^{t+1})}{D_0^{t+1}\,(X^t,Y^t)}\right]$. The geometric mean of these two measures defined the Malmquist productivity change index (Färe et al 1994) and is represented by equation (4) which was further decomposed into two components as denoted by equation (5).

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \sqrt{\left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}\right)\right]} \text{--------------(4)}$$

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left[\sqrt{\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)}\right] \text{----------(5)}$$

The first component of equation (5), $\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)$, measured the change in technical efficiency during the period 2015 to 2021. It provided an account of whether the VDP is progressing nearer to its efficiency frontier over the years or not.

The second part of the equation, $\left[\sqrt{\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right)}\right]$, gave an account of the change in output over the selected periods of time i.e.. 2021 over 2015. It indicated whether or not the frontier is shifting outward during the time period. Values greater than one for either of these components suggest increased productivity growth and values less than one indicate the converse.

Statistical Package for the Social Sciences (SPSS 20), R

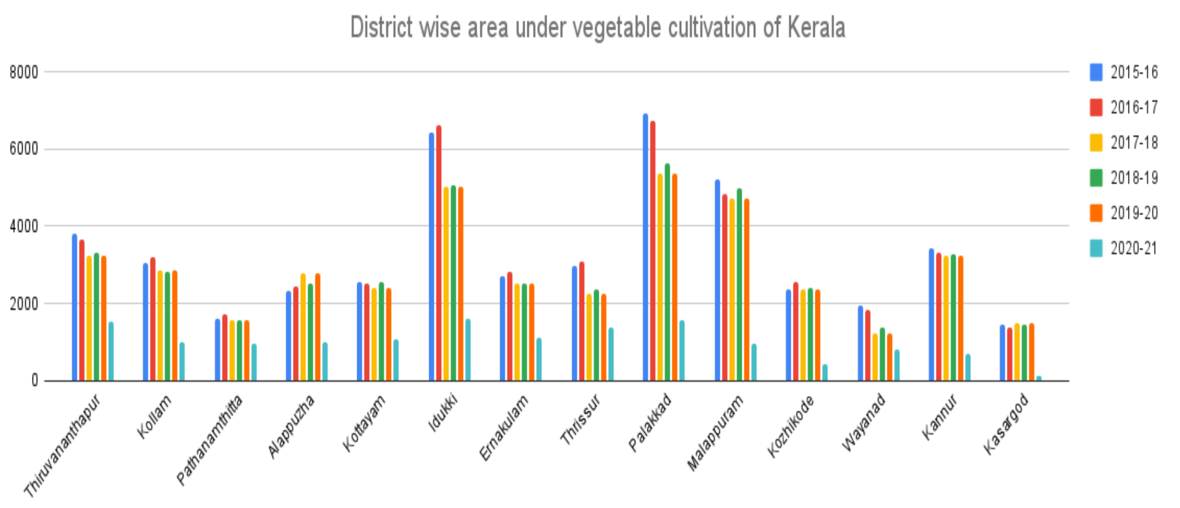


**Figure 2:**Trends of the area under vegetable cultivation among the districts of Kerala during 20015-21

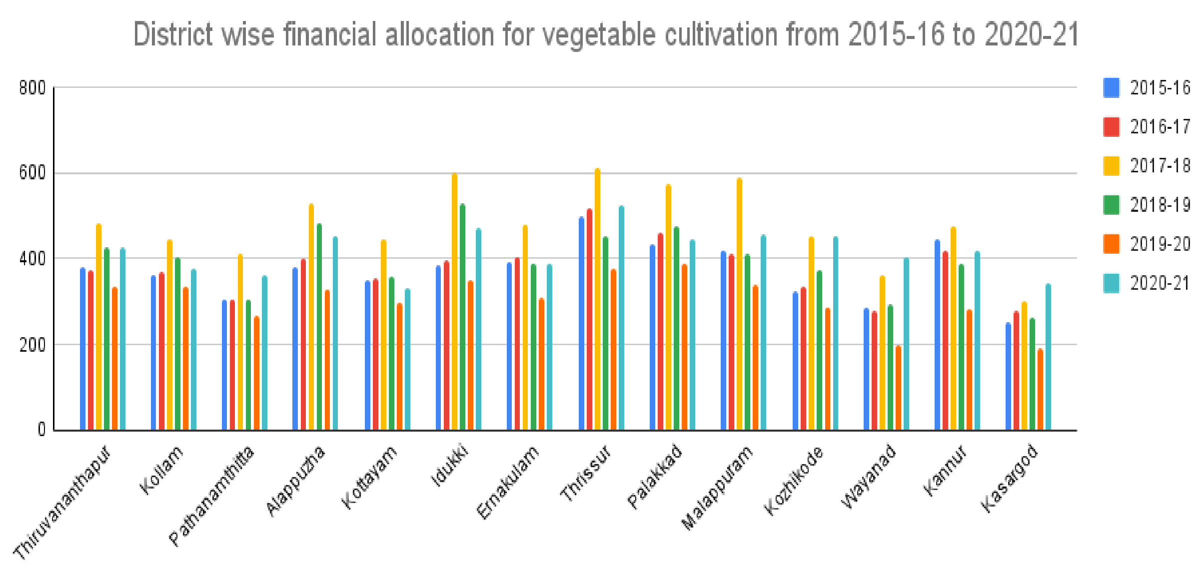


**Figure 3:** District wise total allocation of funds under VDP

Core Team package (2012) - r DEA open-source software, and Microsoft Excel 2007 are the major software packages used for the analysis.

## RESULTS

District-wise area under vegetables in Kerala for the period 2015-2021 is presented in Figure 2. The trend indicated Palakkad and Idukki districts situated in the central and hilly regions of the state respectively, consistently had the highest area under vegetables during the period. However, a steady fall in the area over the years is quite evident despite the implementation of VDP which could be attributed to recurring floods in 2018 and 2019 and COVID 19 lockdown in 2020. Moreover, all the major components under VDP stressed on household vegetable production through terrace cultivation, grow bag cultivation, homestead cultivation, cluster farming etc that has limited reflection in the overall area. The results reiterated the importance of productivity enhancement in improving vegetable production in the state than area expansion as envisaged in the VDP (Deshpande and Bhander, 2003; Umanath and Rajasekhar, 2013; Sunandini et al., 2020). This indicates the need to focus more on popularising hybrids, which received limited thrust under VDP.

The district-wise financial allocation for the various technological components targeted under the program from its initiation in 2015 to 2021 is depicted as Figure 3. The districts of Idukki, Thrissur, Palakkad and Malappuram shared the maximum allocation among the districts throughout the years. Except Idukki, all the three districts that received maximum allocation were from the central zone which also record maximum vegetable production in the state. Based on the annual allocation, components of VDP implemented in the state were categorised as major and minor. Major interventions were the promotion of vegetable production in clusters, home stead cultivation, urban vegetable z in grow bags, terrace cultivation, irrigation infrastructure, awareness programs, and skill development. Also, minor components related to hybrid varieties, waste management, resource recycling, were promoted.

The DEA results showing the technical efficiency of VDP implemented in the 14 districts of Kerala are presented in Table 1. The results indicated that the best technical efficiency score of 1.00 was shared by the districts of Palakkad (PLKD) and Idukki (IDKI) from the central and high-range regions respectively. The result was found consistent throughout the assessment period from 2015-2021. These districts also had the maximum area under vegetables in the state and the highest budget allocation throughout the years. These suggest that these districts shared the best agro ecological and socio-economic situation for vegetable cultivation in the state.

However, Pathanamthitta (PHTA) and Thrissur (TCR) districts from the southern and central regions of the state had TE scores o.588 and 0.558 respectively. It indicates that in order to improve the efficiency of these districts they need to reduce the resources by around 40-45 percent in achieving the same output targets. However, Wayanad (WYND) district in the high range region is closer to the efficiency frontier with TE 0.965 and needs only a reduction of 3.5 percent in resources to achieve efficiency. But the districts of Trivandrum (TVM) in the southern region and Kannur (KNR) in the northern region could be efficient only with a reduction of approximately 22 percent inputs and for Kasaragod (KSGD) (northern region) and Alappuzha (ALPA) (southern region) around 35 percent resource reduction is estimated. Similarly, Kollam (KOLM), from the southern and Ernakulam (EKM), and Malappuram (MLPM) from the state's central regions had to improve their efficiency by reducing 28 percent of the resources spent under the various components of VDP.

It could also be observed from the results that there is a consistent improvement in the technical efficiency of the program over the years as is evident from a rise in the number of districts with a TE score of 1.00. In the initial year of 2015-16 there were only three districts that had a perfect score of 1.00 which improved to nine districts in 2020-21 as presented in Figure 4. Even during the years of floods in 2018-19 and COVID 19 lockdown years of 2020 -2021, there was a consistent improvement in the number of districts that recorded the efficient scores in the state. This could be attributed to the importance gained by vegetables in the Re-build Kerala Initiative (RKI) of the Government of Kerala during the flood rehabilitation works. Also, the popularity gained by vegetables as a protective food that raised immunity levels during the COVID time and the confinement of people to homes that brought people back to agriculture will well explain the improved TE scores of VDP during these crisis periods.

The results presented in Table 2 indicated the overall technical efficiency (TE) of VDP in the state. TE based on the pooled data of investments under the different components of VDP implemented in the state of Kerala from 2015-2021 was found to be 78 percent. It could be inferred from the result that the inputs under the various components could be reduced by 22 percent without affecting the current output. It implied that the vegetable area covered under the VDP could be retained at 39466 ha even when the current total investments under the scheme are reduced by 22 percent. The present use of resources was found to be higher than what was required to achieve the present output in all regions of the state. Similar results are reported in many studies that analyzed input use inefficiency in different cropping systems and project resource use (Shafiq and Rehman, 2000; Coelli et al., 2002; Abdulai et al., 2018). More significantly the highest resource efficiency could be identified in the high-range districts of Idukki and Wayanad which covered high-output areas and had almost consistently low levels of input slacks. Component-wise analysis indicated homestead vegetable clusters (HVC) to have consistently high input slack in all the regions including the most efficient regions of high ranges. An overall reduction of 37819.9 lakh rupees was possible with respect to the state's HVC component during the study period. As such, the contribution of the component needs to be evaluated separately in terms of its contribution towards the nutritional security of the state, especially at the household level. A similar interpretation applies to all other components in all the regions as excess resource use could be observed, though to lower levels. More significantly, the highest resource efficiency could be identified in the high range zone with the districts of Idukki and Wayanad, which covered high output areas and had almost consistently low input slacks on all components except HVC.

Also, the results in Table 2 demonstrated that all most all other components of the scheme had input slack which showed an inconsistent trend over the years. The most efficient component with the least slack score

**Table 1:** Technical efficiency scores of VDP in the districts of Kerala for the period 2015-2021

| Year | Technical Efficiency scores of the districts | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Southern region | | | | Central region | | | | | High range region | | Northern region | | |
| | TVM | KOLM | PHTA | ALPA | KTYM | EKM | TCR | PLKD | MLPM | IDKI | WYND | KZKD | KNR | KSGD |
| 2015-16 | 0.696 | 0.725 | 0.424 | 0.477 | 0.670 | 0.597 | 0.414 | 1.00 | 0.969 | 1.00 | 1.000 | 0.464 | 0.643 | 0.757 |
| 2016-17 | 0.652 | 0.524 | 0.461 | 0.507 | 0.434 | 0.427 | 0.465 | 1.00 | 0.670 | 1.00 | 0.929 | 0.467 | 0.521 | 0.685 |
| 2017-18 | 0.857 | 0.763 | 0.528 | 0.608 | 0.651 | 0.658 | 0.439 | 1.00 | 0.670 | 1.00 | 0.929 | 1.000 | 1.000 | 0.935 |
| 2018-19 | 0.742 | 1.000 | 0.653 | 0.620 | 0.910 | 0.744 | 0.441 | 1.00 | 0.670 | 1.00 | 0.929 | 1.000 | 1.000 | 0.955 |
| 2019-20 | 0.756 | 0.310 | 0.544 | 0.616 | 1.000 | 0.891 | 0.591 | 1.00 | 0.670 | 1.00 | 1.000 | 1.000 | 0.964 | 0.516 |
| 2020-21 | 1.000 | 1.000 | 0.918 | 1.000 | 1.000 | 1.000 | 1.000 | 1.00 | 0.670 | 1.00 | 1.000 | 0.364 | 0.567 | 0.155 |
| Pooled | 0.784 | 0.720 | 0.588 | 0.638 | 0.778 | 0.720 | 0.558 | 1.000 | 0.720 | 1.000 | 0.965 | 0.716 | 0.783 | 0.667 |

**Table 2: Results of input-oriented DEA model for the different regions of the state of Kerala, India**

| Region | Districts | Efficiency score | Slack input variables (Budget expenditure in INR) | | | | | | | | | | Output (Veg area in ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HVC | TC | PUGBC | DGI | IS | AP | SDP | PVC | HVP | OMC | |
| Southern region | Trivandrum, Kollam, Pathanamtitta, Alappuzha | 0.68 | 33453.1 | 5.41 | 2.21 | 3.07 | 0.98 | 0.69 | 1.19 | 14.24 | 1.45 | 0.045 | 9586 |
| Central region | Ernakulam, Thrissur, Palakkad, Malappuram | 0.80 | 41647.4 | 4.1 | 2.6 | 1.5 | 0.30 | 0.20 | 0.10 | 18.30 | 1.30 | 0.00 | 16950 |
| Northern region | Kozhikode, Kannur, Kasargod | 0.72 | 34457.4 | 4.51 | 0.90 | 2.19 | 0.60 | 1.11 | 0.25 | 30.18 | 3.25 | 0.05 | 6190 |
| High range region | Idukki Wayanad | 0.98 | 42026.7 | 0.53 | 1.63 | 0.93 | 0.11 | 0.25 | 0.19 | 21.77 | 1.54 | 0.00 | 6740 |
| **Pooled** | | **0.78** | **37819.9** | **4.04** | **2.00** | **2.02** | **0.52** | **0.53** | **0.47** | **20.19** | **1.78** | **0.02** | **39466** |

HVC-Homestead vegetable cultivation; TC-Terrace Cultivation; PUGBC-Promotion of urban grow bag vegetable cultivation; DGI-demonstration gardens in institutions (combine with school gardens); IS- infrastructural support (combine irrigation, pump sets, rain shelter); AP-awareness programs (publicity funds); SDP-Skill Development Programs (training funds); PVC-Promotion of vegetable clusters, HVP-Hybrid Variety Programs; OMC-other minor components

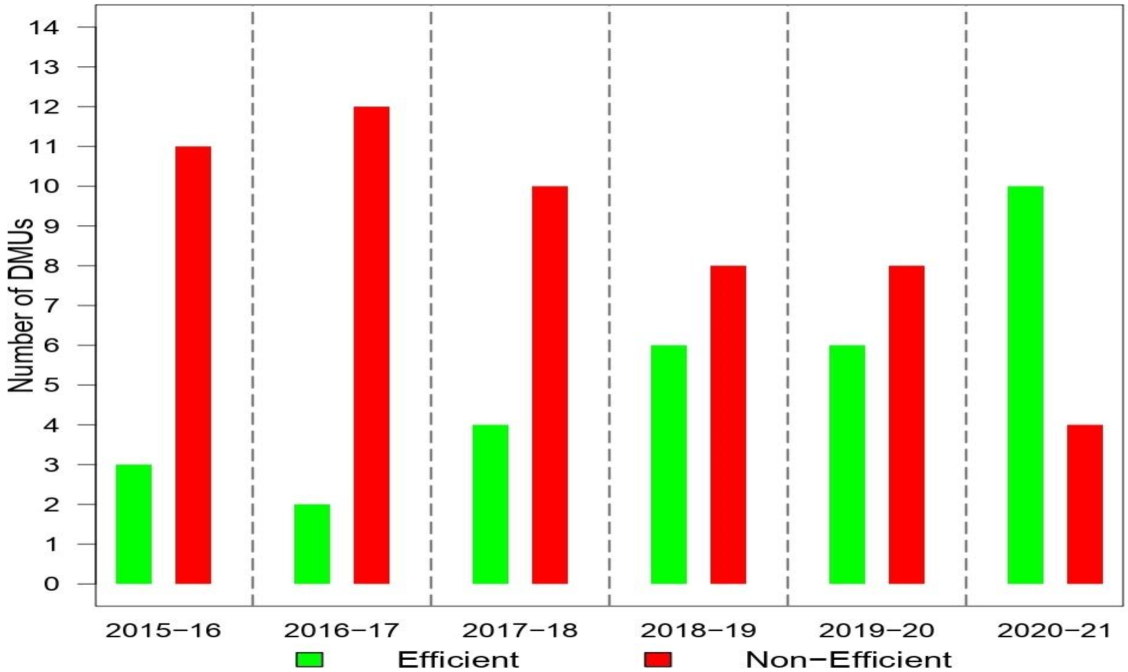


Fig.4. Histogram for efficient and nonefficient DMUs of Kerala from 2015-2021

**Table 3.** Distribution of the DMUs based on technical efficiency (TE) estimates of VDP in Kerala

| DMUs (Districts) | Technical Efficiency (%) | Frequency of DMUs in the TE level |
|---|---|---|
| Pathanamthitta, Thrissur | Below 60 | 2 |
| Alappuzha, Kasaragod | 60 – 70 | 2 |
| Kannur, Kozhikode, Malappuram, Ernakulam, Kottayam, Kollam, Thiruvananthapuram | 70 – 80 | 7 |
| Wayanad | 80 – <100 | 1 |
| Idukki, Palakkad | 100 | 2 |
| Kerala (pooled) | 0.78 | 14 |

was observed to be the other minor components (OMC) which covered waste management, composting, and organic resource recycling. This could be explained in terms of the promotion of carbon neutral strategies to build climate resilience among the farmers. Also, the role of vegetables as a protective food with immunity boosting properties are promoted under the good agricultural practices (GAP) wherein the bio-inputs and recycling have critical role.

**District and year wise evaluation of technical efficiency**

The frequency distribution of the districts based on overall technical efficiencies is reported in Table 3. The results indicated that the efficiencies across the districts varied from 56 to 100 percent with a mean of 79.66 percent. Thus, the performance of schemes that aimed at improving vegetable production in the state varied widely across districts. The commendable disparity among districts in performance could be the result of the inefficient utilization of inputs allotted under the scheme to produce a given level of output. It could be observed from the results that the best-performing DMUs, termed as the reference set identified were Idukki, and Palakkad districts with a performance score of 100 percent. Out of the districts that lag behind the best performers, Pathanamthitta, and Thrissur had the lowest efficiency scores of 0.588 and 0.558 respectively, which implied that there is a possibility of enhancing their efficiency by around 41-44 percent. The majority of districts (Kannur, Kozhikode, Malappuram, Ernakulam, Kottayam, Kollam, Thiruvananthapuram) had an efficiency score in the range of 70-80 percent. This implied that the overall inefficiency is about 20 percent in the state and this highlights the fact that the resources are underutilized and output maximization has not been achieved. The districts of Alappuzha and Kasaragod fall in the categories

**Table 4:** Malmquist productivity index of VDP over the years

| Sl. No. | Years | Technical Efficiency change (effch) | Technological change (tech) |
|---|---|---|---|
| 1 | 2015-2017 | 0.9705 | 0.9823 |
| 2 | 2017-2019 | 1 | 1.0153 |
| 3 | 2019-2021 | 1.0361 | 1.0507 |

**Table 5.** Scale efficiency estimates of VDP for the districts of Kerala

| Districts | CRS TE | VRS TE | SE | RTS |
|---|---|---|---|---|
| TVM | 0.784 | 0.651 | 1.204 | IRS |
| Kollam | 0.791 | 0.656 | 1.206 | IRS |
| PHTA | 0.588 | 0.397 | 1.481 | IRS |
| Alappuzha | 0.638 | 0.535 | 1.193 | IRS |
| Kottayam | 0.778 | 0.604 | 1.288 | IRS |
| Ernakulam | 0.720 | 0.550 | 1.309 | IRS |
| Idukki | 1.00 | 1.00 | 1.00 | CRS |
| Thrissur | 0.558 | 0.541 | 1.031 | IRS |
| Palakkad | 1.00 | 1.000 | 1.00 | CRS |
| Malappuram | 0.954 | 0.876 | 1.089 | IRS |
| Kozhikode | 0.716 | 0.684 | 1.047 | IRS |
| Wayanad | 0.898 | 0.636 | 1.412 | IRS |
| Kannur | 0.783 | 0.689 | 1.136 | IRS |
| KSGD | 0.667 | 0.228 | 2.925 | IRS |
| Pooled | 0.777 | 0.646 | | |

CRS TE- Constant rate Scale Technical efficiency; VRS TE- Variable Rate Scale Technical Efficiency; SE – Scale Efficiency; RTS- Returns to Scale, CRS-Constant Rate to Scale; IRS-Increasing Rate to Scale

of 60 -70 percent and Wayanad in the 80 – < 100 percent efficiencies respectively. It is evident from the results that there is a possibility to attain similar levels of output by reducing resource use.

Changes in technical efficiency of VDP over the period 2015 to 2021 were further evaluated using the Malmquist productivity change index. The index being composed of distance functions based only on quantity data, made no assumptions regarding VDP's productivity change behaviour (Grifell-Tatjé& Lovell 1996). The analysis provided additional information related to changes in technical efficiency (effch) and technology change (tech). Changes in technical efficiency indicate how the DMUs are getting closer to the production frontier over time and changes in technology show whether the production frontier is moving outwards over time. The results of the cross-sectional data analysis are presented in Table 4 which showed an increase in Malmquist productivity index for the years 2017-2019 and 2019-202. On the contrary, 2015-2017 showed an inefficiency of 0.9705 for 2015 and 2016. It could be inferred that in 2015-2017 the efficiency was on the lower side compared to the projects implemented after 2017. Technological change (tech) shows the output increase over constant input (Gulati, 2011). Here also, the initial years of 2015-17 needed improvement. The output increase, i.e., the increase in the area under vegetable farming as compared to the investments made, eventually increased over the years. This can be attributed to the concerted efforts from the government agencies to improve vegetable self-sufficiency in the state under flood relief and COVID-19 lockdown-related components of VDP. Also, the results suggest that even though the physical area and capital inputs under VDP recorded an overall reduction in the state over the years, the technical efficiency of VDP recorded a steady improvement over the years. More significantly, the observed improvement in technological efficiency of VDP has contributed to improve household vegetable consumption and nutritional security of the state. This warrants detailed study to delineate the strategies adopted during 2019-21 that recorded high efface and tech values for further policy streamlining.

### Scale Efficiency

The results of technical efficiency across the CRS and VRS scale types are presented in Table 5. As per the results, Palakkad from the central region and Idukki from the high range region had the highest efficiency scores with both CRS and VRS scores of 1.00 (100 %). This was followed by the Malappuram district of the central region with a VRS efficiency score of around 88 percent. The CRS had the highest technical efficiency estimate of 78 percent whereas the VRS had an efficiency estimate of 65 percent for the pooled data as shown in Table 5.

Overall, all the districts exhibited increasing returns to scale except Idukki and Palakkad. This suggested that an increase in the use of inputs would lead to a more than proportionate increase in output. None of the districts in the state recorded a Decreasing Rate to Scale (DRS) in any of the implementing years.

## DISCUSSION

The trend of the area under vegetables in the state indicated steady fall over the years. This is quite evident despite the prevalent congenial agro-ecological and socio-economic conditions for vegetable production. This reiterated the importance of productivity enhancement in improving vegetable production rather than targeting area expansion (Deshpande and Bhander, 2003; Malalarasaran and Rajasekhar, 2013; Sunandini et al., 2020).). In terms of resource allocation under the different components of VDP shown in Figure 3, except for Idukki, all the three districts that received maximum allocation were from the central zone and were the leading vegetable producers in the state (GOK, 2020).

It is quite interesting to note the districts of Palakkad (PLKD) and Idukki (IDKI) were the most efficient districts in terms of implementation of VDP in the state. In fact, these districts shared the maximum area under vegetables in the state (GOK, 2020) and as such received the highest budget allocation consistently throughout the years. Thus, it could be inferred that these districts shared the best agro-ecological and socio-economic situation for vegetable production. Waldman et al. (2021) also, in their study, reported that socio-economic factors had a greater influence in agricultural production and livelihood of farmers. The results further support the recommendation of targeted vegetable production by concentrating on the districts and regions with favourable agro-ecological situations rather than spreading the scarce resources over all regions. The results could well guide the extension managers in the state to identify Idukki and Palakkad as the benchmark districts for vegetable production in the state. It could also be utilized to improve strategies for the currently inefficient districts.

The consistent improvement in the TE scores among the districts even in years of flood and COVID could be attributed to the importance gained by vegetables in the Re-build Kerala Initiative of the Government of Kerala as part of the flood rehabilitation works. It aimed to build resilience and mitigate risk, adopting the concept of *Build Back Better* (BBB) (RKI, 2019). Also, the popularity gained by vegetables as a protective food that raised the immunity levels during the COVID time and the confinement of people to home that brought people back to agriculture will sufficiently explain the improved TE scores of VDP during these crisis periods (Aman and Masood, 2020).

It could be observed from the results in Table 2 that the current level of resource use was higher than what was required to achieve the present output in all regions of the state. The TE scores indicated total inefficiencies of around 20 percent, which comprised the number of proportional reductions in resources and slack estimates. The results are in accordance with the findings of Nandy et al. (2018) that over-utilization of input resources affected production and could challenge the profitability of the farming community as well as sustainability of agricultural systems. Moreover, the highest inefficiency observed for the homestead vegetable cultivation (HVC) component could be interpreted in terms of the minimal contribution possible from homestead cultivation of vegetables towards the selected output of the area under vegetable cultivation in the study. Hence, an evaluation in terms of its contribution toward household nutritional security is warranted to bring out its real contribution.

The results also implied that the extension officers in 12 districts of the state (except Idukki and Palakkad) could not facilitate efficient resource use resulting in the wastage of resources. The low TE score of the KSGD district needs further analysis in light of the ongoing exclusive organic agriculture programs implemented in the district for the past 10 years unlike the other districts in the state. Most of the components under VDP relate to the integrated packages of vegetable production which warrants a scientific mix of chemical and bio inputs. This must have impeded with the implementation of VDP in KSGD as reflected in the low TE scores. Overall, there were increasing returns to scale (IRS) in the majority of districts in the implementation of VDP in the state during the early years from 2015-2020. The highest percentage (86%) of DMUs with IRS was during 2016-17, followed by 2015-16 (78.6%) and 2017-18 (71%). According to Banker et al. (2004), IRS is reported when the output increases by a larger proportion than the increase in inputs during the implementation process of VDP. The most efficient component with the least slack score was observed to be the other minor components (OMC) of VDP that covered waste management, composting, and organic resource recycling, etc. This could be explained in terms of the promotion of carbon-neutral strategies to build climate resilience among vegetable farmers. Also, the role of vegetables as a protective food with immunity-boosting properties is promoted under good agricultural practices (GAP) wherein the bio-inputs and recycling have a critical role. More investments under the components of awareness programs (AP) and skill development programs (SDP) would be beneficial in improving the overall efficiency of the program. The results are in line with the findings of Onuwa et al. (2021), which emphasized the role of extension agencies in building farmers skills and capacity, which in turn can ensure technical efficiency and food security. Similar results are reported in many other studies that analysed input use inefficiency in different cropping systems and project resource use (Shafiq and Rehman, 2000; Coelli et al., 2002).

The results also suggest that at present, the demand for vegetable development services exceeds supply and hence the need for competitiveness is not felt. However, with the emerging presence of multiple extension service agencies, the performance metrics of services become an important criterion for evaluation. As such, the results will be crucial for productivity improvements and in deciding the viability of program implementation. However, with the emerging presence of multiple extension service agencies, the performance metrics of services become an important criterion for evaluation. As such, the results will be crucial for productivity improvements and in deciding the viability of program implementation. This also indicates the need for skill development of extension officers in resource management along with advanced production strategies that will lead to the enhanced production and nutritional security.

Vegetable development programs play a major role in enhancing vegetable production in a safe-to-eat manner and attaining self-sufficiency in the sector. Performance evaluation and benchmarking could help the VDPs to become more productive and efficient. The study used Data Envelopment Analysis and the Malmquist productivity index as the empirical tools of measurement. In spite of the massive use of Data Envelopment Analysis (DEA) models for efficiency estimations in scientific research, no studies exist on the technical efficiency of vegetable development programs in Kerala. A complete understanding of diminishing costs and maximizing returns is indispensable, not just to derive expenditure projections but also to direct policymakers on program guidelines and the desirability of specific budget proposals. DEA enabled differentiation between efficient and inefficient DMUs, the critical method used to quantify efficiency in public decision-making units, suggesting a reduction in input allocation for optimal performance. Although decision making and formulation of VDPs are the responsibility of policy makers, all the stakeholders of the VDP can provide guidance and inputs for the formulation and implementation of programmes.

The current research shows technical efficiencies, scale efficiencies, and productivity growth as the evaluation measures of VDP implemented in Kerala for 2015-2021. Of the 14 units studied, efficiencies across the units varied from 56 to 100 percent with a mean of 79.66 percent. The units identified as inefficient should increase all outputs in the proportion indicated in the score of efficiency. It was concluded 2016-17 had 12 non efficient DMUs and the VDP investments are not having the desired reflection in results. Malmquist productivity index revealed that in 2015-2017 the efficiency was on the lower side compared to the projects implemented after 2017.

Thus, the study helped to benchmark the locative efficiency of DMUs in input use and produce outputs in optimal proportions. Also, the regional disparity in vegetable development can be well addressed using the results, tapping vegetables' economic and nutritional potential. But the further improvement of the best performers will depend on factors such as innovative technologies and other related changes in the vegetable production process that have the potential to contribute to sustainable farming systems. This is because the efficiency improvement will also depend on input price, production scale, market demand for the produce, etc., which were not considered in the present study as it focused on evaluating the efficiency of VDP expenditure (inputs) and area covered (output). Overall, the study aids to evolve more resourceful measures of evaluation protocols that find application in the analysis of agricultural development programs. The study results to rank investments in vegetables, resulting in augmented financial prospects for smallholder farmers, thereby providing healthy diets for all. Thus, evaluations on similar lines are recommended to yield guidelines for the sustainable management of agricultural development programs. Overall, the study has data restrictions and there is a need for expansion of work in this area. Forthcoming researches should include the use of excluded inputs and outputs and extensions of DEA to acclimatize the model to specific situations.

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**Declaration of conflicting interest**

The authors have no conflicting interest in the publication of the article and the article is original and has not been published nor is under consideration for publication by another publisher/Journal.

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