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# Forecasting of pest induced yield loss in rice using Damped Trend Exponential Smoothing model for Balesore District of Odisha

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### Abstract
The production of rice requires to be elevated to meet the demand for growing population. As the cropping area is shrinking due to urbanization, biotic and abiotic stress; there are two ways through which the production can be enhanced. One method with development of HYVs in accordance with micro climate and other one diminishing the crop loss through biotic stresses like pest, disease etc. This study has focused on prediction of pest induced yield loss for future based on past time series data, using Holt's Damped Trend method. Firstly, by using Dhaliwal method, yield loss due to pest in rice is obtained from 2001-2018. Using these data, Holt's damped trend method for prediction is carried out. The best parameter combination is selected based on their performance on training and testing data set of yield loss due to pest and the combination with least error has been selected for this data. The parameter combination $\alpha$=0.7, $\beta$=1, $\varphi$=0.7 has least information criteria and error metrices. Based on the choosen parameters, prediction for next seven years has been carried out along with their confidence interval.

**Keywords:** Damped trend exponential smoothing, damping factor, forecasting, MAPE, pest induced yield loss

### Introduction
In India, majority of the population consumes rice as a staple food and rice is the primary agricultural commodity. It is the farming fraternity's oldest source of income. The production of rice needs to be increased to meet the demand of growing population. Earlier agriculture production was carried out in large cultivated areas, whereas now-a-days, urbanization diminishes the cropping area as a result production becomes less. Moreover, disengagement of the farmer fraternity from doing agriculture for several reasons like environmental calamities (drought, flood, etc.), ecological stress (pest and disease attack), stress due to nonavailability of marketing place, increase in cost of cultivation and lack of stimulation to the farming community are significant causes of less production.

Odisha, one of the potential states of India, constitutes ten agro-climatic zones with thirty districts out of which there were only 13 in numbers before 1993. The farmers of the State show less interest in agricultural activities due to shared environmental and biological hazards. Cyclones hit Odisha almost every year. The climate change scenario in Odisha is reflected very well in the form of erratic rainfall, late onset of monsoon, rise in temperature, which readily affects the rice life cycle from sowing to harvesting stage.

With the development of new crop varieties, pests of crop mutate themselves according to the level of hazards. The erratic climate change pattern also helps the pests to grow andmultiplicate faster. Different pests infest the crop at different growing stages, viz., vegetative, reproductive, and ripening. The list of major pests with their damaging growth stages along with stage of crop infestation are enlisted in Table-1.

**Table 1:** Key pest of rice, their damaging stage and affected plant growth stages

| Sl No. | Pest | Scientific Name | Damaging stage of Pest | Stage of crop infestation |
|---|---|---|---|---|
| 1 | Yellow Stem Borer | *Scirpophaga incertulas* (Lepidoptera: Pyralidae) | Larva | Vegetative and Reproductive |
| 2 | Leaf Folder | *Cnaphalocrocis medinalis* (Pyralidae: Lepidoptera) | Larva | Vegetative |
| 3 | Rice Brown Plant Hopper (BPH) | *Nilaparvata lugens* Stal (Hemiptera: Delphacidae), | Nymph and Adult | Vegetative and Reproductive |
| 4 | White-backed Plant hopper (WBPH) | *Sogatella furcifera* (Horvath), | Larva | Vegetative and Reproductive |
| 5 | Rice Swarming Caterpillar | *Spodoptera mauritia*(Noctuidae: Lepidoptera) | Larva | Vegetative |
| 6 | Case worm | *Nymphula depunctalis* | Larva | Vegetative |
| 7 | Rice hispa | *Dicladispa armigera* | Larva and Adult | Vegetative |

The insect pest attack severely damages the crop by accounting for around 25% of crop loss (Singh, 2014; Dhaliwal & Arora, 2015) [1] in the case of rice crops. Particular for any particular pest the economic threshold level (*ETL*) for a pest determines the pest management steps. Above *ETL* directs to adopt proper management practices to prevent the economic injury level (*EIL*) of crop due to pest. The pest incidence density defines the *ETL* for a particular pest, whereas the lowest population of pests that will cause economic damage is called *EIL*. In Odisha, based on the severity of the pest attack, the cultivated area is classified into three categories, i.e. (i) Low intensity, (ii) Moderate intensity, and (iii) High intensity. The low infestation intensity is determined below *ETL*, whereas the rest two categories are classified above *ETL*, which signifies taking the necessary steps to prevent *EIL*.

## Materials and Methods

The yield data of Balesore district has been obtained from Department of Agriculture and Farmers' Empowerment, Government of Odisha (GoO). The yield loss data have been estimated and the detailed procedure are discussed later. The period of yield loss data is considered as 2001 to 2018.

## Analytical Procedure

### Estimation of yield loss of rice due to pest

Government of Odisha has published two *kharif* manual in the year 2001 and 2007 respectively. This manual contains the rice varieties are suitable and grown in different agroclimatic zones along with their standard yield. Based on that for the selected districts we calculated average standard yield by averaging the standard yield of varieties grown in that districtin two periods viz. one from 2001 to 2007 and other one from 2008 to 2018. The difference between the average yield and observed yield will be considered as yield loss due to all other factors. Out of the total loss, 25% the total loss will be considered to be the loss due to pest (Dhaliwal et. al., 2015) [1]. Likewise for each district from 2001 to 2018 the estimation of yield loss of rice due to pest was carried out.

### Holt's Damped Trend or Damped Trend with Exponential Smoothing

This is an extension of Holts Linear trend that adds a damping parameter to regulate the trend from extrapolating too aggressively into the future. In this method the time series divided into three components viz., level $L_t$, trend $b_t$ and damping parameter $\varphi$whose ranges are 0 to 1.

### The equations for individual components are

$$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + \varphi b_{t-1}),$$

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)\varphi b_{t-1},$$

Finally, the forecast equation for $m$ periods ahead is given by

$$F_{t+m} = L_t + b_t . (\frac{1-\varphi^m}{1-\varphi}),$$

For $\varphi = 1$, this becomes Holts Linear Trend and for $\varphi = 0$, trend dies out completely and forecasts converge to level.

## Results and Discussions

### Estimation of rice yield loss due to pests

The *kharif* manual published by Department of Agriculture and Farmers' Empowerment, Government of Odisha (GoO) during 2001 and 2008 suggest the varieties recommended for different districts of Odisha. After obtaining the standard yield for each district, the yield loss has been obtained by differencing the observed yield from standard yield. The pest induced yield loss has been obtained by considering 25% of total yield loss. So, the yield loss due to pests is obtained from 2001 to 2018.

**Table 2:** Estimation of Yield loss due to pests of Balesore district

| Year | Standard Yield (Kg/ha) | Actual Yield (Kg/ha) | Yield Loss (kg/ha) | Yield Loss due to pest (Kg/ha) |
|---|---|---|---|---|
| 2001 | 4015.73 | 1733 | 2282.73 | 570.68 |
| 2002 | 4015.73 | 823 | 3192.73 | 798.18 |
| 2003 | 4015.73 | 1499 | 2516.73 | 629.18 |
| 2004 | 4015.73 | 1713 | 2302.73 | 575.68 |
| 2005 | 4015.73 | 1448 | 2567.73 | 641.93 |
| 2006 | 4015.73 | 1334 | 2681.73 | 670.43 |
| 2007 | 4015.73 | 1452 | 2563.73 | 640.93 |
| 2008 | 4125.58 | 1315 | 2810.58 | 702.65 |
| 2009 | 4125.58 | 1451 | 2674.58 | 668.65 |
| 2010 | 4125.58 | 1718 | 2407.58 | 601.90 |

| | | | | |
|---|---|---|---|---|
| 2011 | 4125.58 | 2149 | 1976.58 | 494.15 |
| 2012 | 4125.58 | 1548 | 2577.58 | 644.40 |
| 2013 | 4125.58 | 844 | 3281.58 | 820.40 |
| 2014 | 4125.58 | 2003 | 2122.58 | 530.65 |
| 2015 | 4125.58 | 1474 | 2651.58 | 662.90 |
| 2016 | 4125.58 | 2720 | 1405.58 | 351.40 |
| 2017 | 4125.58 | 2175 | 1950.58 | 487.65 |
| 2018 | 4125.58 | 2473 | 1652.58 | 413.15 |

The Holt's Linear trend could not capture the trend properly which produced absurd results. But the Holt's damping trend yielded good results. The damping technique has been implemented to prevent the trend estimate from becoming too sensitive to data fluctuations. In Holt's method with two parameters, one for level smoothing ($\alpha$) and the other for trend smoothing ($\beta$) if a damping factor (φ) is added, then this model turns to be a Holt's Damped trend model or Damped trend in exponential smoothing. For the seven districts, identification of best model parameters and forecasting the future would be carried out using Holt's Damped Trend model.

**Prediction of rice yield loss due to pest for Balesore**

The entire data (2001 to 2018) are splitted into training component and testing component in 80:20 ratio. After comparing multiple configurations of the Holt's damped trend model for forecasting rice yield loss due to pests in Balesore district. The model with lowest information criteria values should be selected. The model with α= 0.7, β= 1, φ= 0.7 emerged as the most balanced and accurate in information criterions as well as in error metrices. This model achieved an MAPE for testing data as 16.29% which is lowest among the selected α, β and φ and the MAPE for training data comes out to be 19.97% which indicates that the model fits well to the training and testing data sets. The chosen damping factor (φ= 0.7) ensures that the model accounted for trend without escalate excessively over the forecast horizon. Other error metrices like MAE, MSE and RMSE were also least as compared to other parameter combinations. After fitting the best combination of α, β and φ the observed vs forecast values for testing set data with their difference is checked to interpret the fit.

**Table 3:** Comparison of observed and in sample forecasted rice yield loss for testing data set.

| Year | Observed yield loss(kg/ha) | Forecasted yield loss (kg/ha) | Absolute Difference | Test MAPE (%) |
|---|---|---|---|---|
| 2015 | 662.895 | 549.864 | 113.031 | 16.29 |
| 2016 | 351.395 | 488.270 | 136.874 | |
| 2017 | 487.645 | 445.154 | 42.491 | |
| 2018 | 413.145 | 414.973 | 1.827 | |

Oni and Y.O. Akanle (2018) [4] studied on application of smoothing model to forecast cassava production. In their study they found that damped trend model exhibited better results than double exponential method. The damping factor furter smoothened the unnecessary spike in the dataset resulting better model fitting. Implementing, the final chosen parameters to whole data set, the future forecasting values can be generated. For Balesore district, next seven-year (2019-2025) pest induced yield loss were predicted successfully along with 95% confidence interval to curb the uncertainty.

**Table 3:** Seven year forecast value with 95% confidence interval for rice yield loss due to pest in Balesore.

| Year | Forecast (kg/ha) | Lower Bound (95%) | Upper Bound (95%) |
|---|---|---|---|
| 2019 | 549.8648 | 249.9779 | 849.7517 |
| 2020 | 488.2705 | 188.3835 | 788.1574 |
| 2021 | 445.1545 | 145.2675 | 745.0414 |
| 2022 | 414.9732 | 115.0863 | 714.8602 |
| 2023 | 393.8464 | 93.95945 | 693.7333 |
| 2024 | 379.0576 | 79.17065 | 678.9445 |
| 2025 | 368.7054 | 68.8185 | 668.5924 |

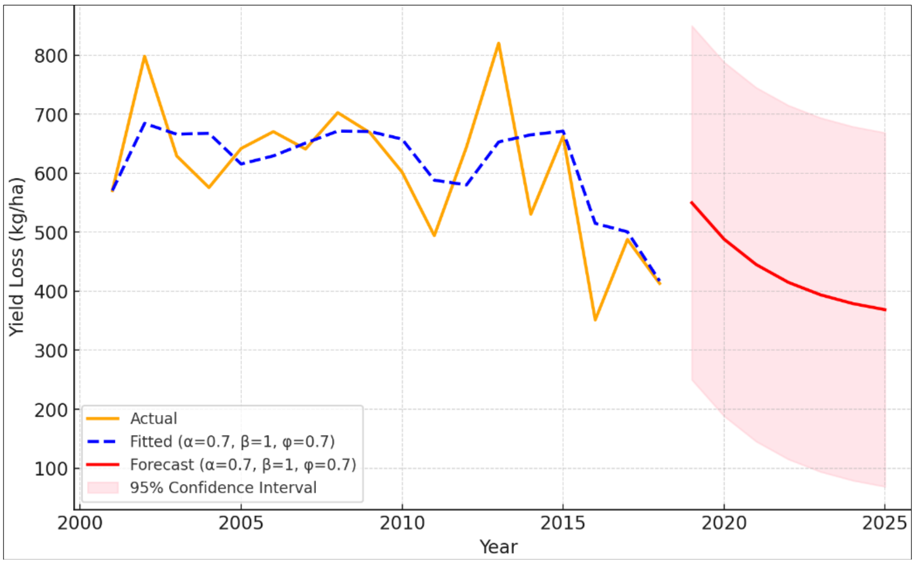


**Fig 1:** Rice Yield Loss due to pest projection for Balesore

## Conclusion

Diminishing the yield loss in rice is one of the method to increase the production. In this study, yield loss has been obtained by differencing the standard yield of the district and actual yield of the district. The pest induced yield loss has been estimated using the Dhaliwal's method. According to his method, 25% of toal yield loss is due to pest. Based on the time series data of yield loss due to pests, the future yield loss due to pests has been forecasted using Holt's. Damped Trend method. The best parameter combination having least information criterion and error metrices will be shortlisted to predict the future yield loss due to pests. The parameter combination α=0.7, β=1, φ=0.7 has least information criteria and error metrices. It has obtained 16.29% MAPE for testing data set. Using this configuration, future forecast from 2019-2025 has been made with the 95% confidence interval.

**Table 4:** Performance metrices of Holt's Damped Trend model for Balesore rice yield loss due to pest under various α, β and φ.

| Sl No. | Alpha | Beta | Phi | Train MSE | Test MSE | Train RMSE | Test RMSE | Train MAE | Test MAE | Train MAPE | Test MAPE | AIC | BIC | HQIC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.7 | 1 | 0.7 | 23410.08 | 8329.885 | 153.004 | 91.268 | 124.505 | 73.556 | 19.974 | 16.290 | 150.853 | 154.048 | 147.675 |
| 2 | 0.7 | 0.9 | 0.8 | 24505.98 | 8413.310 | 156.544 | 91.724 | 128.537 | 72.504 | 20.559 | 16.466 | 151.493 | 154.689 | 147.316 |
| 3 | 0.9 | 0.6 | 0.6 | 21018.34 | 10434.520 | 144.977 | 102.150 | 111.562 | 82.483 | 17.979 | 16.749 | 149.344 | 152.539 | 145.167 |
| 4 | 0.7 | 0.8 | 0.9 | 25114.51 | 9074.418 | 158.476 | 95.260 | 131.116 | 71.045 | 20.901 | 16.820 | 151.837 | 155.032 | 147.659 |
| 5 | 0.9 | 0.5 | 0.7 | 21614.26 | 10011.060 | 147.018 | 100.055 | 114.970 | 81.279 | 18.450 | 16.865 | 149.736 | 152.931 | 145.558 |
| 6 | 0.8 | 0.7 | 0.7 | 22299.07 | 9047.479 | 149.329 | 95.118 | 119.645 | 78.133 | 19.189 | 16.866 | 150.172 | 153.368 | 145.995 |
| 7 | 0.9 | 1 | 0.4 | 19385.2 | 12268.360 | 139.231 | 110.763 | 101.276 | 87.352 | 16.497 | 16.900 | 148.212 | 151.407 | 144.034 |
| 8 | 0.8 | 1 | 0.5 | 20608.56 | 9748.548 | 143.557 | 98.735 | 110.900 | 81.858 | 17.930 | 16.913 | 149.069 | 152.264 | 144.891 |
| 9 | 1 | 0.3 | 0.8 | 21480.35 | 11079.180 | 146.562 | 105.258 | 112.280 | 84.444 | 17.966 | 17.105 | 149.649 | 152.844 | 145.471 |
| 10 | 1 | 0.7 | 0.4 | 18927.2 | 13452.640 | 137.576 | 115.986 | 97.996 | 89.718 | 15.982 | 17.114 | 147.877 | 151.072 | 143.700 |

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