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Comparative Efficiency of Lactation Curve Models Using Irish Experimental Dairy Farms Data

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Background

- Milking quotas were abolished in the European Union in April 2015. As a free market, milk yield and price fluctuations pose a logistical challenge for both milk producers (farmers) and processors (creameries).
- Currently there is a 10% variance of milk supply with short term (weekly) fluctuations per year in Ireland (Oct 2014).
- The Irish dairy industry may face problems where nationwide milk yield cannot be predicted precisely:
  - Over/ Under capacity.
  - Price volatility.
- Both producers and processors want to receive more precise milk production information.

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Objectives

- The aim of this study was to test ten existing milk production forecast models and to select the most successful modelling techniques based on the validated results.

- Design and implement a data-driven selection algorithm which can generate optimal results dynamically.

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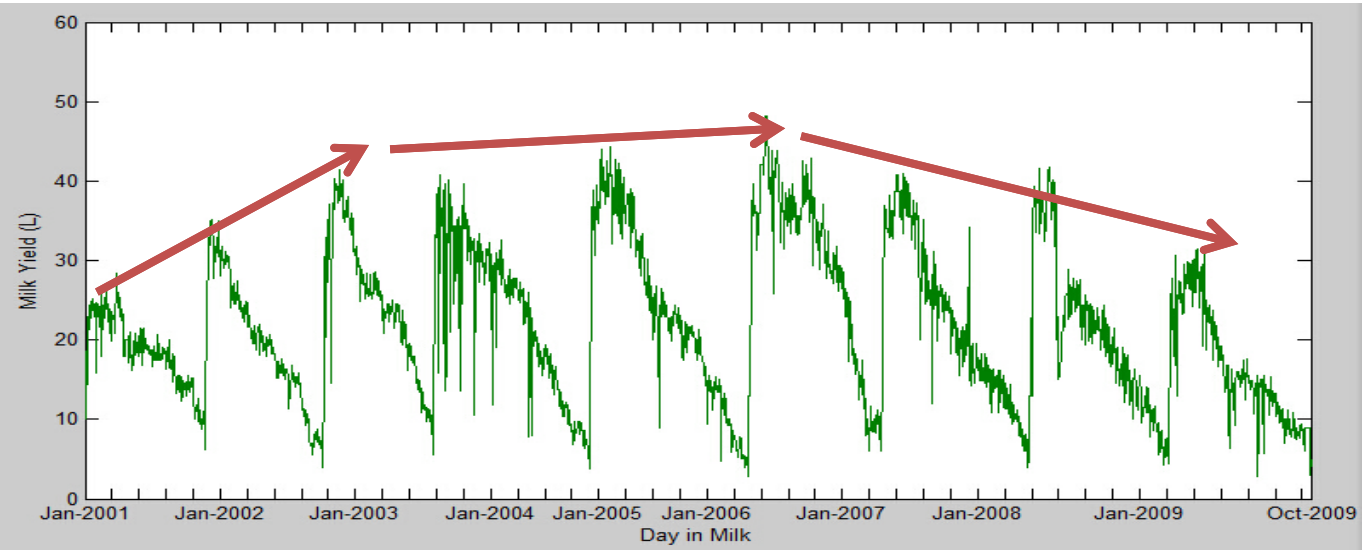
Data

- The empirical data including milking records and cow information was obtained from dairy farms situated in the south of Ireland, over a period of 6 years (2001 to 2009).

- The raw data consisted of cow information and milking records. Cow information contained calving date and lactation number. Each milking record contained date of milking, time of milking, identity number of cow, and milk yield.

Data Classification - by biological features

Sample of individual cow daily yield record



By parity and date :

- 1, 2, >=3, year 2004-2009

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Data

- The randomly selected sample herd of 100 cows consisted of 25 cows, 25 cows, 50 cows in parity one, parity two and parity three or more, respectively.
- The parity composition of the sample herd was kept identical to that of the regional herd population (Donnellan et al., 2011; Donnellan et al., 2015).
- The corresponding milk production data for this sample herd were pre-processed into two parts. One was daily herd milk yield from past years (2004-2008) for training and the other was the latest year (2009) for validation.

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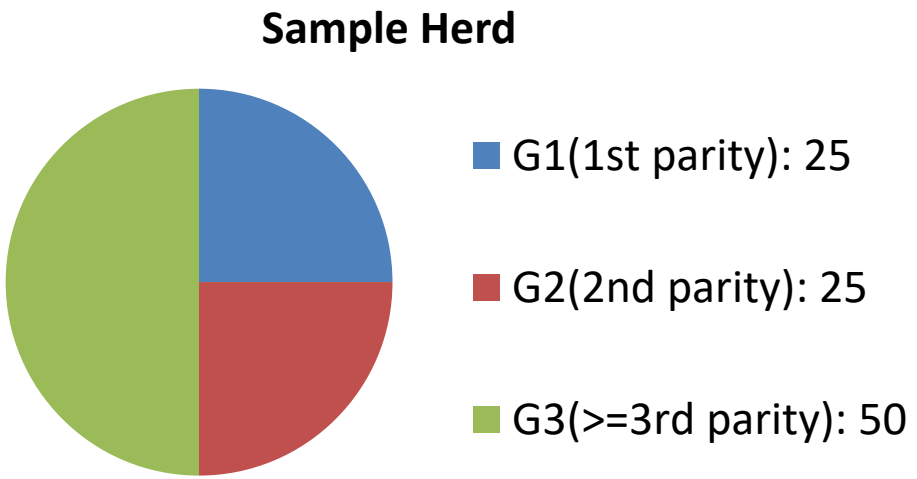
Data

- The instant of sample herd in this study
  - 100 randomly selected cows
  - daily accumulative milk yield records
    - Training: 2004-2008
    - Validation: 2009



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Lactation Curve Models

#	Model	Author	Prediction Horizon	Statistical Criteria
1	Incomplete Gamma	Wood	365 days	SSE R^2 RMSE RPE
2	Polynomial	Ali and Schaeffer	365 days	
3	Adaptive Polynomial	Quinn et al.	365 days	
4	Legendre Polynomial	Kirkpatrick et al.	365 days	
5	Cubic Splines	Green and Silverman	365 days	
6	Log-quadratic	Adediran et al.	365 days	
7	Multiple Linear Regression	Sharma and Kasana	365/30/10 days	
8	Static Artificial Neural Networks	Lacroix et al.	365/30/10 days	
9	Surface Fitting	Zhang et al.	365/30/10 days	
10	Nonlinear Auto Regressive Model with Exogenous Input	Murphy et al.	365/30/10 days	

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Simulation Configuration

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Training Data	Model	Prediction Target
Average daily yield (2004-2008)	Curve Fitting	Daily Yield of 2009
Day of year(2004-2008)	Regressive Dynamic	
Number of cows milked(2004-2008)		
Daily Milk yield (2004-2008)		

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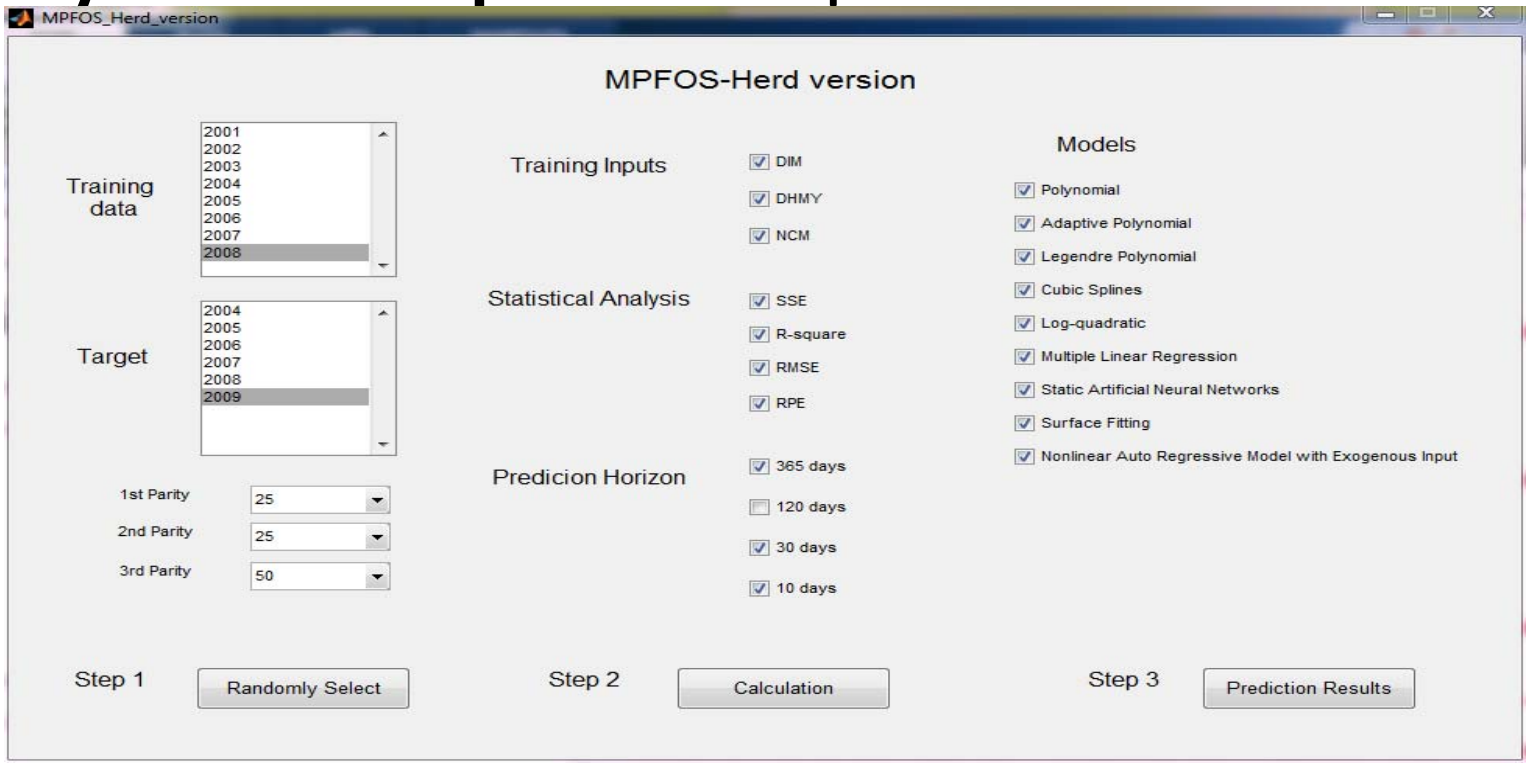
System Input - Graphical User Interface



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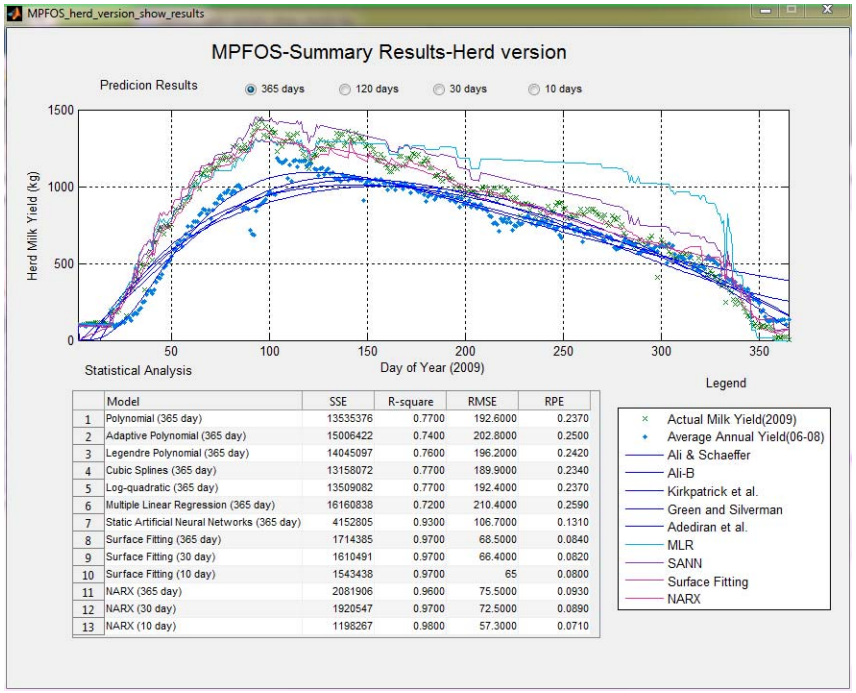
System Output



	Model	SSE	R-square	RMSE	RPE
1	Polynomial (365 day)	13535376	0.7700	192.6000	0.2370
2	Adaptive Polynomial (365 day)	15006422	0.7400	202.8000	0.2500
3	Legendre Polynomial (365 day)	14045097	0.7600	196.2000	0.2420
4	Cubic Splines (365 day)	13158072	0.7700	189.9000	0.2340
5	Log-quadratic (365 day)	13509082	0.7700	192.4000	0.2370
6	Multiple Linear Regression (365 day)	16160838	0.7200	210.4000	0.2590
7	Static Artificial Neural Networks (365 day)	4152805	0.9300	106.7000	0.1310
8	Surface Fitting (365 day)	1714385	0.9700	68.5000	0.0840
9	Surface Fitting (30 day)	1610491	0.9700	66.4000	0.0820
10	Surface Fitting (10 day)	1543438	0.9700	65	0.0800
11	NARX (365 day)	2081906	0.9600	75.5000	0.0930
12	NARX (30 day)	1920547	0.9700	72.5000	0.0890
13	NARX (10 day)	1198267	0.9800	57.3000	0.0710

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Statistical analysis results (365-day)

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#	Model	SSE	R^2	RMSE	RPE
0	the Average Annual Yield Method	16,459,024	0.76	169.3	21.6%
1	Incomplete Gamma (365 day)	18,899,195	0.72	181.4	23.1%
2	Polynomial (365 day)	17,445,018	0.74	174.2	22.2%
3	Adaptive Polynomial (365 day)	19,216,996	0.71	182.9	23.3%
4	Legendre Polynomial (365 day)	18,434,740	0.72	179.1	22.8%
5	Cubic Splines (365 day)	18,071,088	0.73	177.3	22.6%
6	Log-quadratic (365 day)	16,516,409	0.76	169.5	21.6%
7	Multiple Linear Regression (365 day)	13,961,242	0.80	133.9	17.1%
8	Static Artificial Neural Networks (365 day)	3,446,890	0.91	97.2	12.6%
9	Surface Fitting (365 day)	2,097,183	0.96	75.8	9.7%
10	NARX (365 day)	2,253,494	0.95	78.6	10.0%

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Statistical analysis results (10-day)

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#	Model	SSE	R^2	RMSE	RPE
0	the Average Annual Yield Method	16,459,024	0.76	169.3	21.6%
9-1	Surface Fitting (365 day)	2,097,183	0.96	75.8	9.7%
9-2	Surface Fitting (30 day)	1,824,517	0.97	70.7	9.0%
9-3	Surface Fitting (10 day)	1,660,354	0.97	67.5	8.6%
10-1	NARX (365 day)	2,253,494	0.95	78.6	10.0%
10-2	NARX (30 day)	2,050,143	0.96	75.0	9.5%
10-3	NARX (10 day)	1,268,021	0.98	58.9	7.5%

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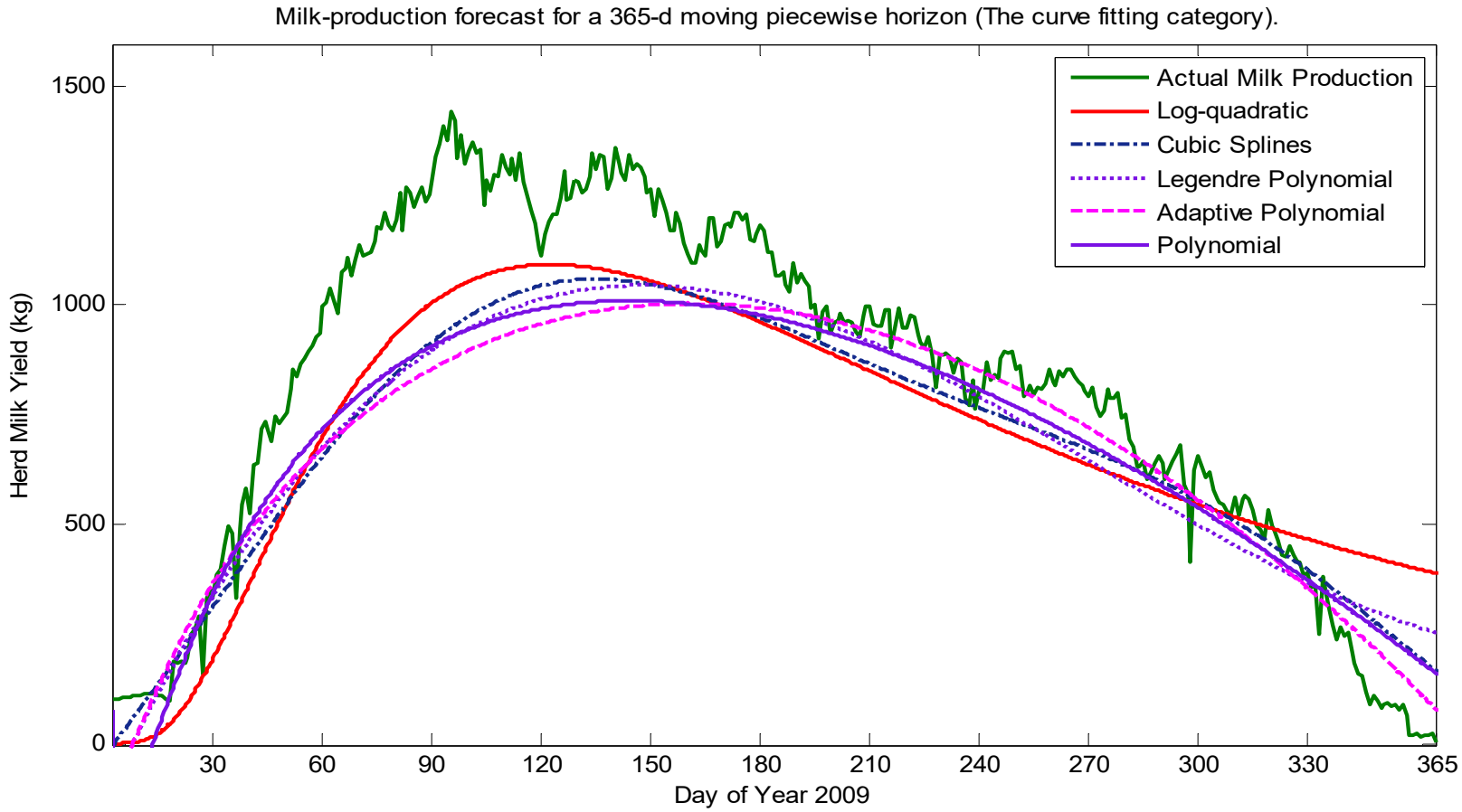
Prediction Results(365-day)



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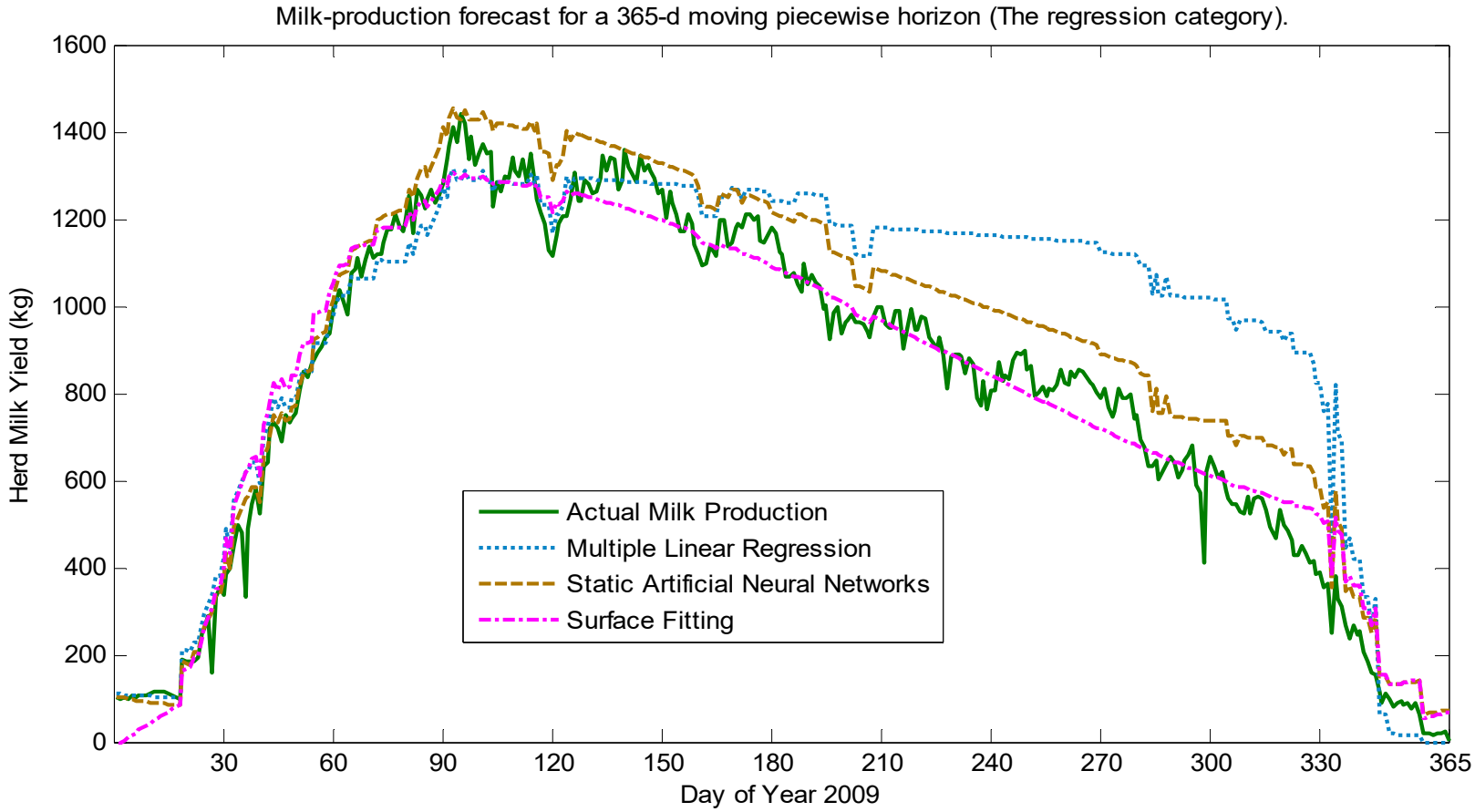
Prediction Results(365-day)



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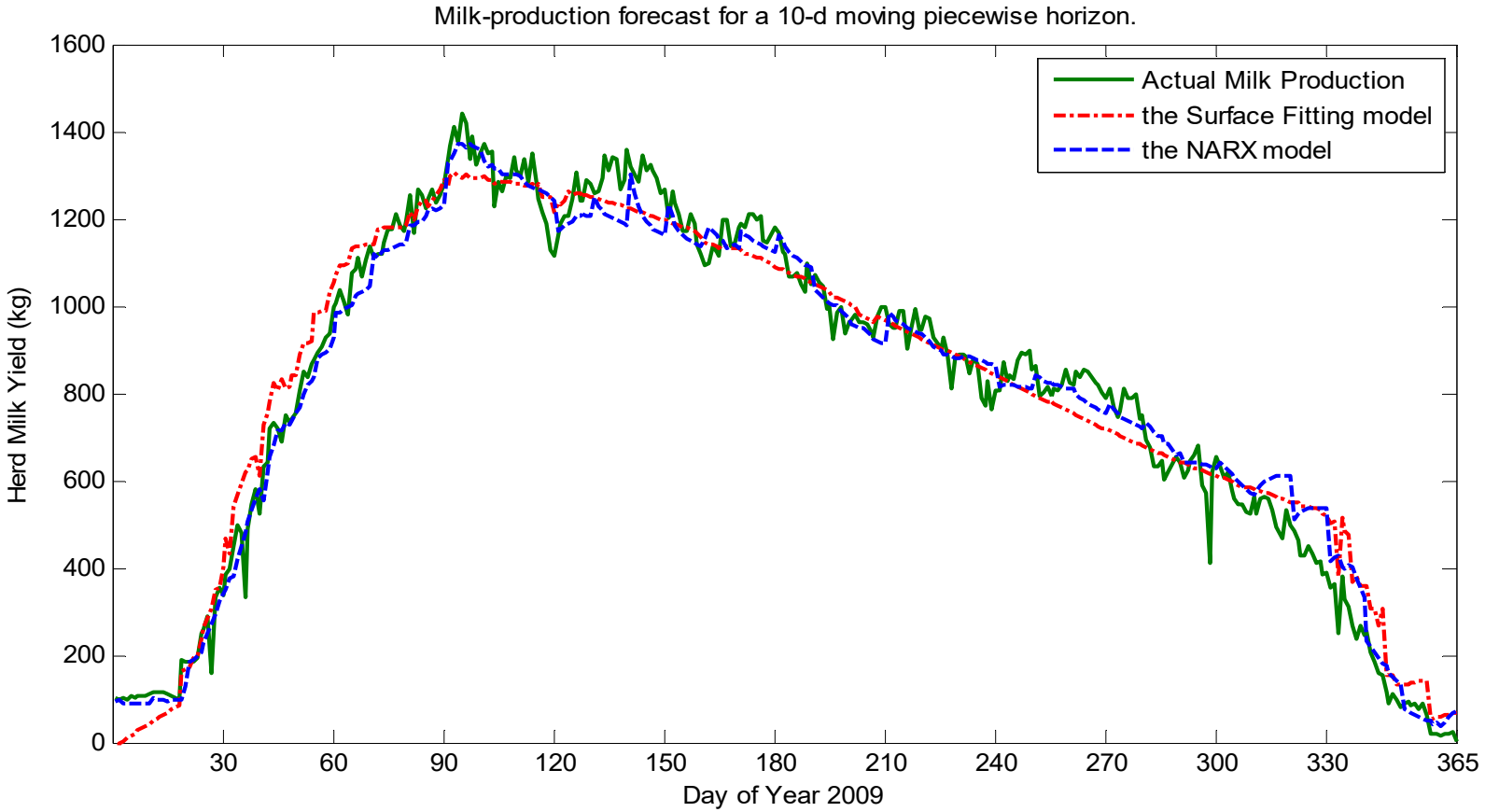
Prediction Results(10-day)



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Conclusion

- In this study, ten existing milk production forecast models were tested and evaluated. The Surface Fitting model proved to be the best fitting model in the 365-day forecast, better than established techniques such as curve fitting models or the MLR model, and also more sophisticated techniques such as the SANN model or the NARX model.
- Only when the prediction horizon was shortened to 10-days, the NARX model showed a better forecasting accuracy than the Surface Fitting model.
- The experimental results of this study support the hypnotizes that the Surface Fitting model and the NARX model provided the most accurate milk production forecast for the sample herd from Irish dairy farms, for long-term (365-day), medium-term (30-day) and short-term (10-day) forecast horizons, respectively.

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Thanks
&
Questions?

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