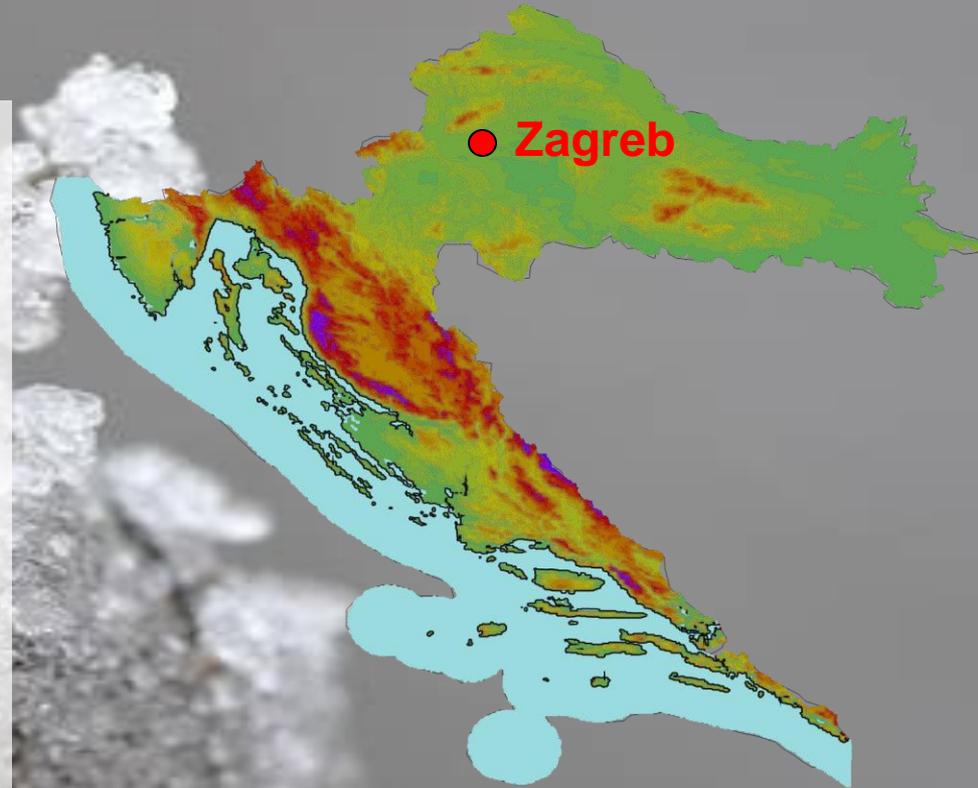


Apple phenology and application of Utah model in Croatia

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Introduction

- The best region for the apple cultivation in Croatia is the continental area, particularly central Croatia
- The mountainous and Adriatic areas are generally unsuitable to growth apples
- Too short vegetation period is in the mountainous part and too mild winter in the Adriatic coast
- There are usually an individual apple trees in these regions, which are grown near houses



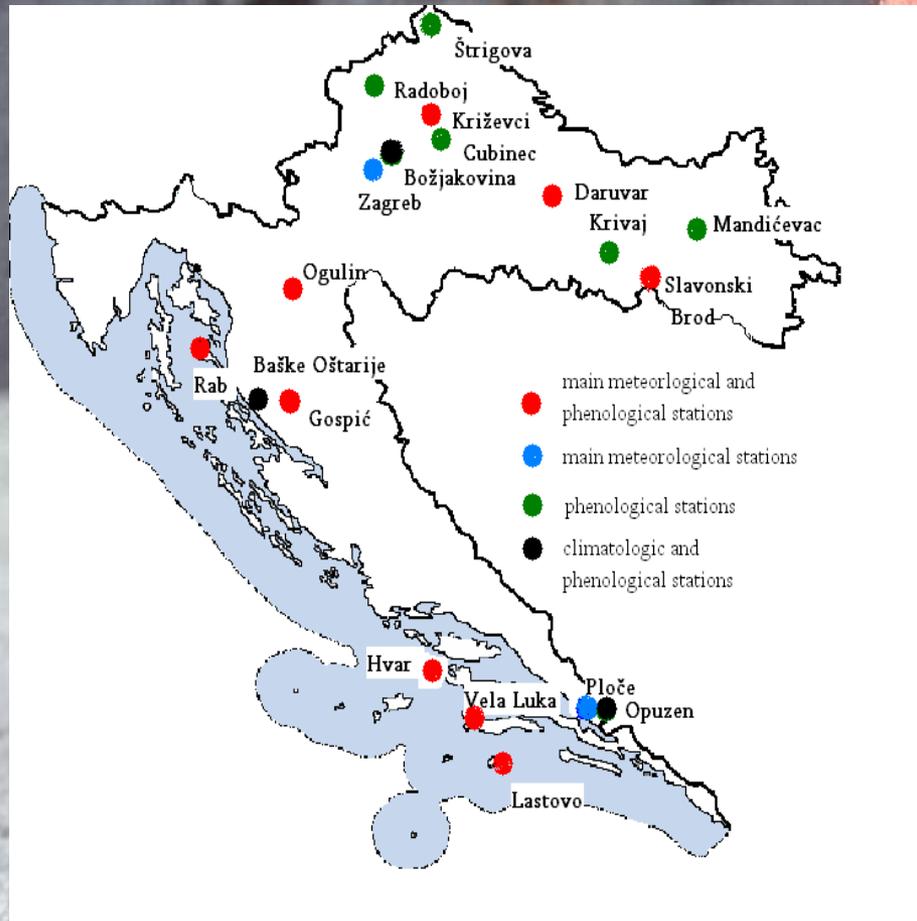
Main goal

- Investigate the impact of climate change on growth and development of different varieties of apple in Croatia
- As air temperature impact is also very important for plants in winter, determination of chill units during winter dormancy should be investigated.

Winter dormancy

- Winter dormancy starts with leaf falling and ends with circulation of juices and bud swelling – protects buds from the effects of cold weather and is defined by chill units (CU)
- If the buds do not receive sufficient chilling temperatures during winter to completely release dormancy, trees will develop one or more of the physiological symptoms associated with insufficient chilling: delayed foliation, reduced fruits and reduced fruit quality

Phenological and meteorological data



- **17 phenological stations**
- **6 apple varieties**
- autumn older: Bobovec, Canada and Kolacarka,
- autumn newer: Jonathan and Golden Delicious
- the earliest variety: Petrovaca
- **8 phenological phases:**

UL - beginning of leaf unfolding

BF - beginning of flowering

FF - full (general) flowering

EF - end of flowering

RF - first ripe fruits

RP - fruit ripe for picking

CL - colouring of leaves

FL - leaf fall

Period: 1979-2009 → 1961-1990

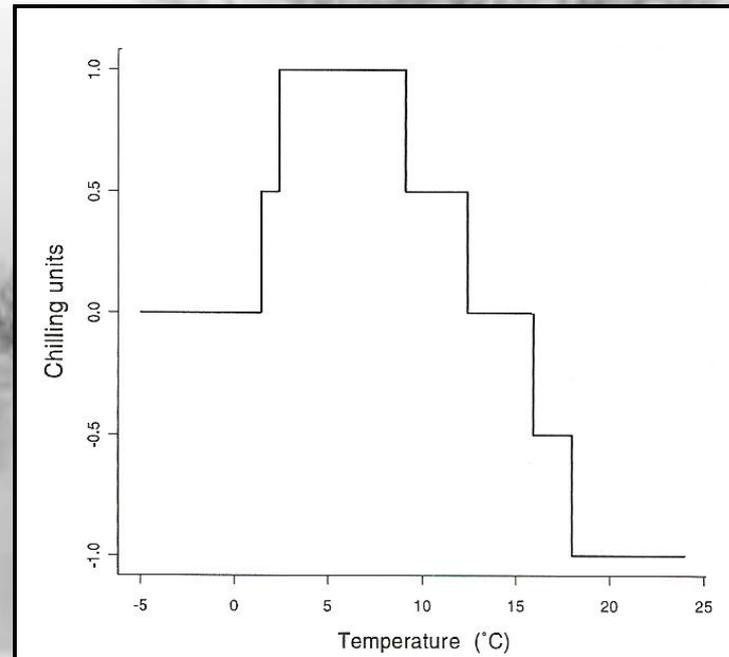
- **Hourly air temperature data:**
7 main meteorological stations in the period 2001-2010

Method

- **Utah model** – chill units (CU) during winter dormancy (Richardson, 1974; Rea and Eccel, 2006)

Chill units: $900 < CU < 1250$ – normal start of vegetation period

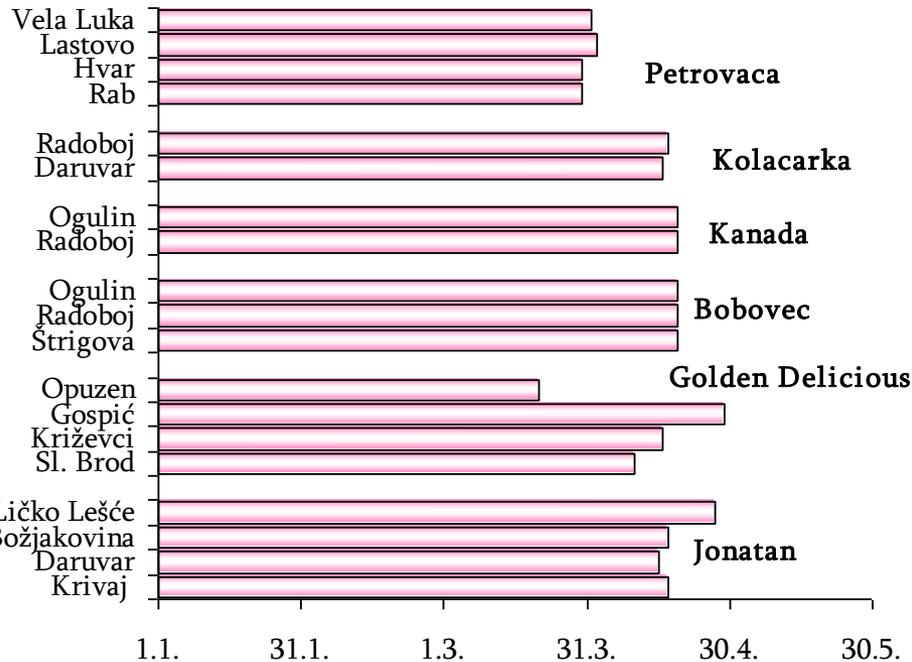
temperature (°C)	CU
<1.4	0.0
1.5-2.4	0.5
2.5-9.1	1.0
9.2-12.4	0.5
12.5-15.9	0.0
16.0-18.0	-0.5
>18.0	-1.0



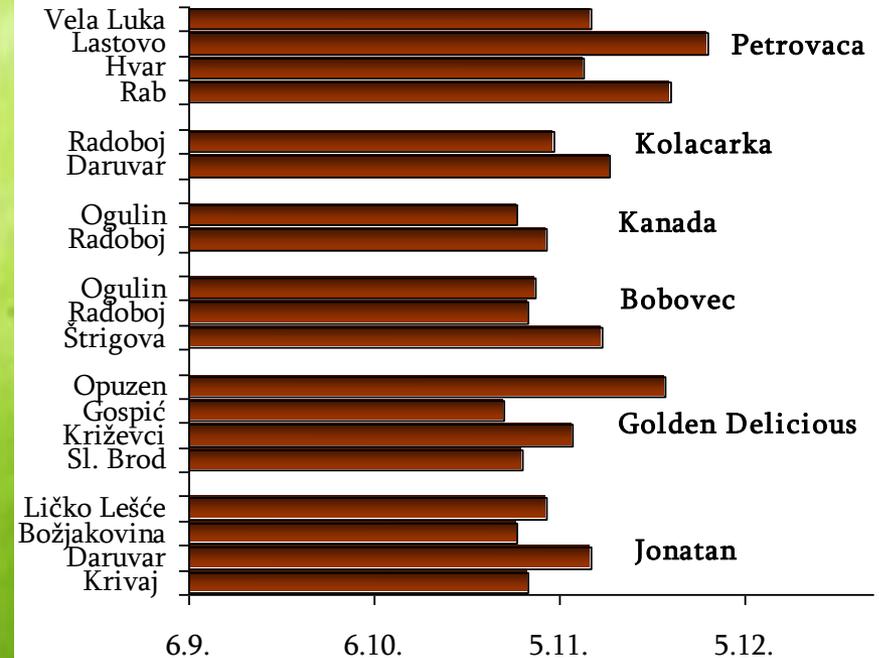
- The Utah model is proposed an accumulation of CU according to a temperature-dependent broken line

Mean dates of apple phenophases

Beginning of flowering



Leaf fall



In the continental Croatian vegetation of different varieties of apples begins in the first half of April and ends in the first half of November. In the mountainous area the growing season is shifted toward to the end of April, and it ends in early November. The earliest vegetation was observed in coastal regions where the growing season begins in late March and lasts through the end of November.

Comparison of mean dates

phenophase	UL	BF	FF	EF	RF	RP	CL	FL
Continental part - Deviation of the period 1991-2009 from 1961-1990								
Krivaj – newer variety Jonathan								
Δ mean	-6	-3	-4	-2	-1	0	-5	-11
Daruvar – older variety Kolačarka								
Δ mean	-1	-2	-2	0	-5	-6	-4	2

- Shortening of vegetation period of newer apple varieties show in the continental Croatia but the vegetation period of older apple varieties did not significantly changed.

Linear trends

Autumn older varieties

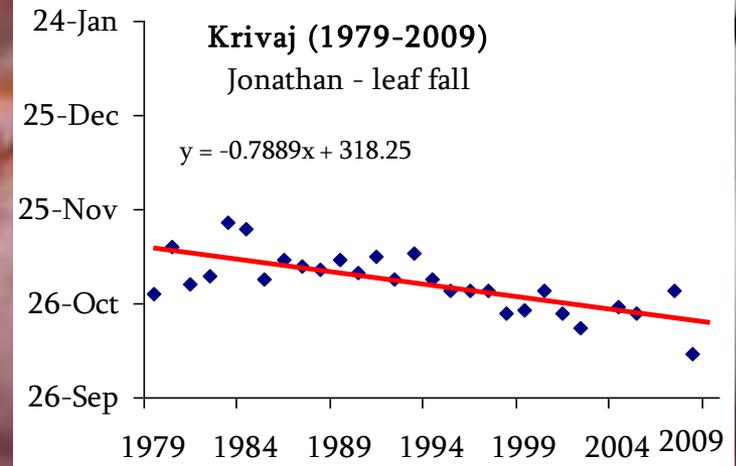
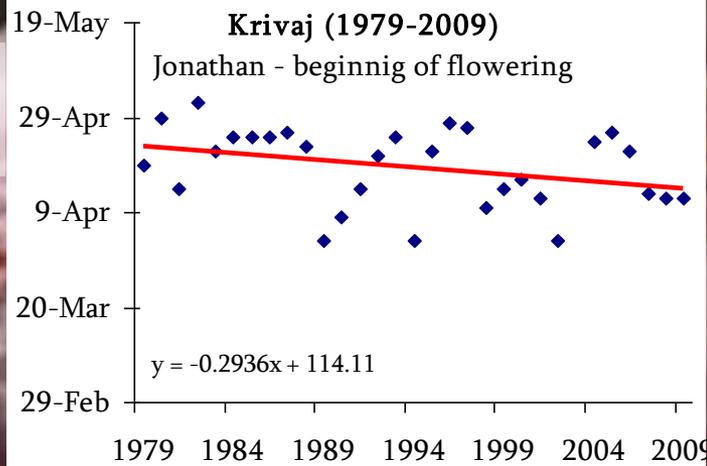
Radoboj (1979-2009)	Bobovec	Canada	Kolacarka
Phenophase	Trend	Trend	Trend
UL	-4.1	-3.1	-4.2
BF	-3.8	-3.3	-2.9
FF	-4.8	-1.5	-4.1
EF	-3.3	-2.2	-2.1
RF	-4.7	-2.1	-2.0
RP	-3.0	-0.3	-0.7
CL	-4.4	-5.5	-3.4
FL	-1.7	-7.2	-0.7

- Beginnig of vegetational period is shifted earilier in spring, but the end of vegetation period is also shifted eariler – the length of vegetation period was not significantly changed

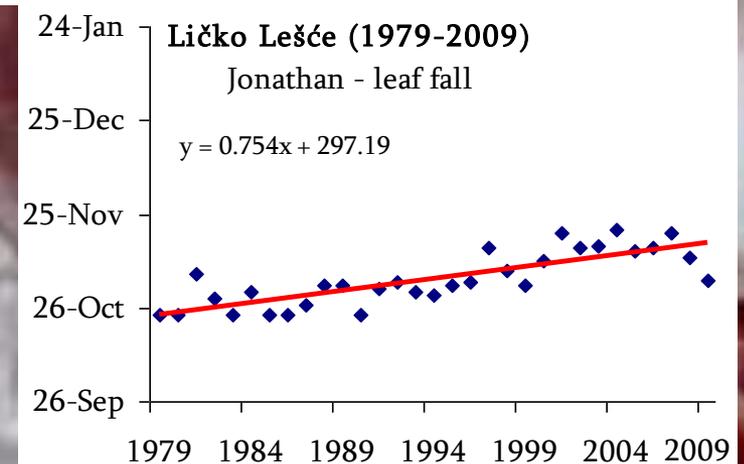
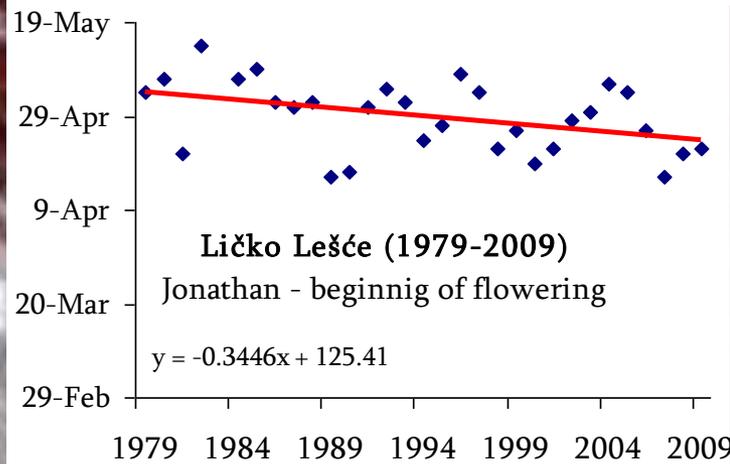
Linear trends

Continental Croatia

Newer varieties
Jonathan



Mountainous Croatia



- Autumn newer apple varieties show greater sensitivity to change in length of vegetation period over the last three decades
- Shortening vegetation period is observed in continental Croatia but prolongation in mountainous Croatia by 6-9 days/decade

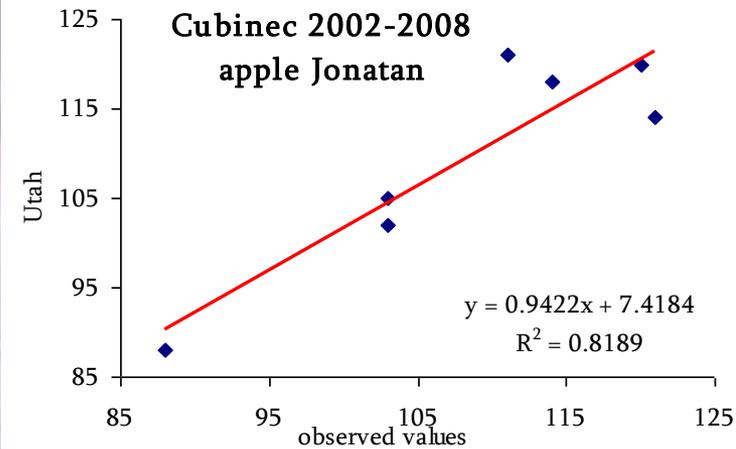
Utah model

- Estimation of beginning of flowering for different varieties of apple (Jonathan, Golden Delicious, Petrovaca)

Station	R
Variety Jonatan	
Cubinec	0.96
Baške Oštarije	0.99
Ličko Lešće	0.99
Opuzen	0.96
Variety Golden Delicious	
Slavonski Brod	0.98
Gospić	0.98
Opuzen	0.99
Variety Petrovača	
Cubinec	0.99
Hvar	0.84

**Cubinec
Continental
part:**

**Hvar
Adriatic
island:**



year	UTAH	observed
2002	20.3.	24.3.
2003	26.3.	27.3.
2004	10.4.	11.4.
2005	1.4.	11.4.
2006	29.3.	11.4.
2007	25.3.	4.4.
2008	20.3.	24.3.

Chill units

900 < CU < 1250

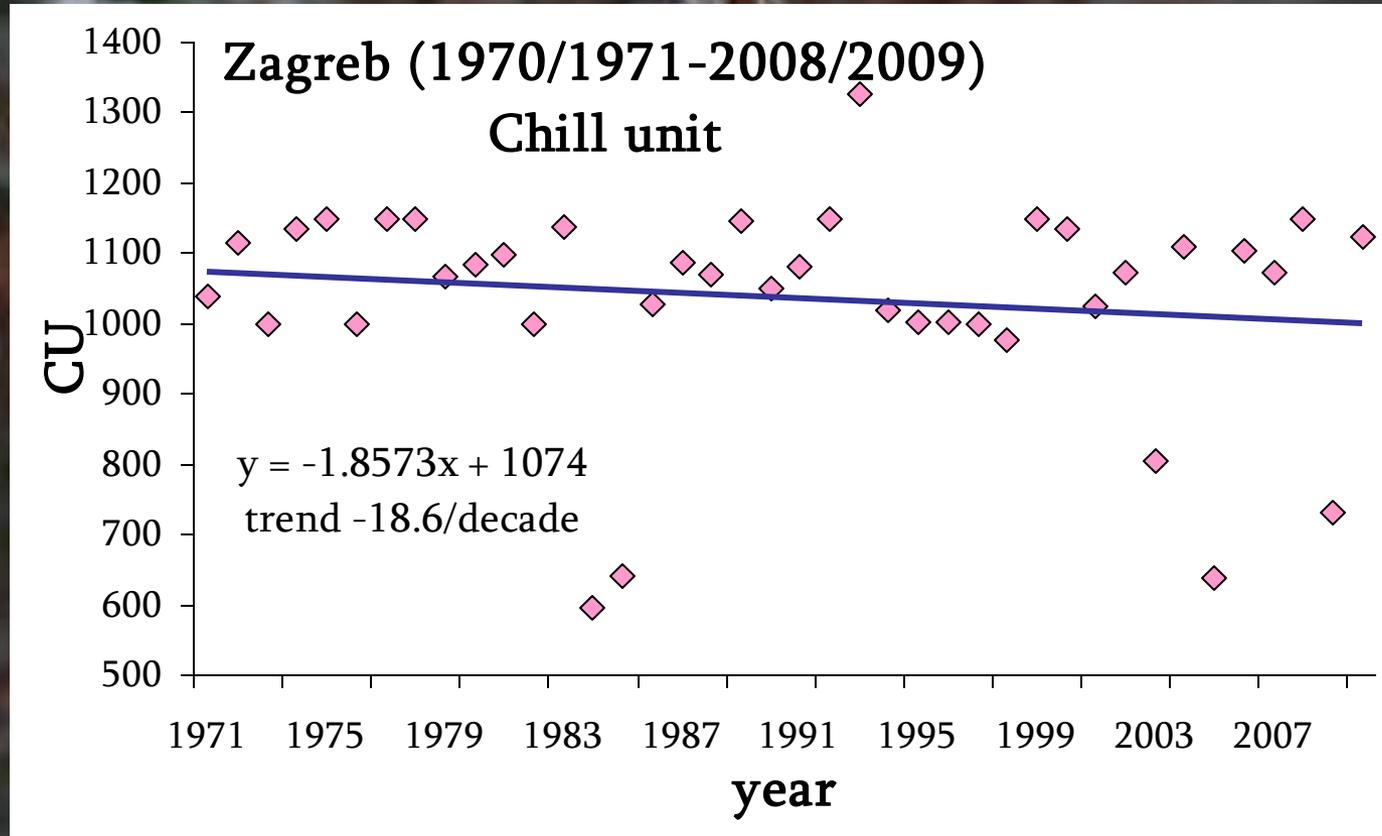
Continental Mountainous Adriatic

	Jonathan Cubinec	Golden Del. Gospic	Petrovaca Hvar
year	CU	CU	CU
2001/2002	1071	/	910
2002/2003	857	1083	903
2003/2004	1169	988	1030
2004/2005	1107	1246	610
2005/2006	<u>1299</u>	1001	585
2006/2007	1124	1043	504
2007/2008	1250	1130	1007
2008/2009	1250	1128	1022
2009/2010	1250	1022	1015
mean	1153	1080	843

▪The least CU is estimated in the mid-Adriatic area, which is consistent that this region is unfavourable for the cultivation of apples.

▪The mountainous region could be suitable for apple growing in future

Linear trend of chill units



Linear trend indicates the decrease in chill unit in continental Croatia. If the decrease in CU will intensify, the apple cultivation could be at risk in future.

Conclusion

- Autumn newer varieties of apple shown greater sensitivity than older varieties to the change of vegetation period in the last three decades
- Shortening of apple vegetation is observed in continental Croatia and prolongation in mountainous Croatia that shows possibility of better cultivation of apple in mountainous area
- Utah model is good indicator for determination of favourable or unfavourable region of apples in Croatia. It is proved that the Adriatic area is unsuitable for apple growing
- Decrease in chill unit in the continental Croatia could be negative effect on apple cultivation in future

THANK YOU



Kolacarka



Bobovec

Canada



Jonathan



Golden Delicious



Petrovaca