Coupled Modeling of Hydro-sedimentary Transfer Processes and Socio-Economic Dynamics Evaluating Public Policies to Control Runoff and Erosion: Case Study in Normandy (France)

Patault, E.[1,*], Ledun, J.[2], Landemaine, V.[3], Soulignac, A.[4], Richet, JB.[2], Ramaekers, F.[1], Cikowski, N.[1], Cabaz, B.[4], Fournier, M.[1], Ouvry, JF.[2], Rinaudo, JD.[4], Cerdan, O.[3], Laignel, B.[1]

[1]University of Rouen, UMR CNRS 6143 M2C, Normandy, France [2]AREAS, 76460 Saint-Valéry-en-Caux, France [3]BRGM, 45060 Orléans, France [4]BRGM, 34000 Montpellier, France

*Corresponding author @: edouard.patault1@univ-rouen.fr

Paper number: PA41D-1141

AGU 100 FALL MEETING

Context & Objectives

- Normandy region is located in the European loess belt, and therefore, very sensitive to runoff and erosion → 0.5-10 t/ha/yr (Cerdan et al., 2010)
- Excessive density of muddy flooding → 10-20/km² (Boardman et al., 2019)
- Since 2000, high financial support from several public institutions to reduce erosion and runoff impacts (flooding, damages to infrastructures, turbidity in drinking water, etc.)

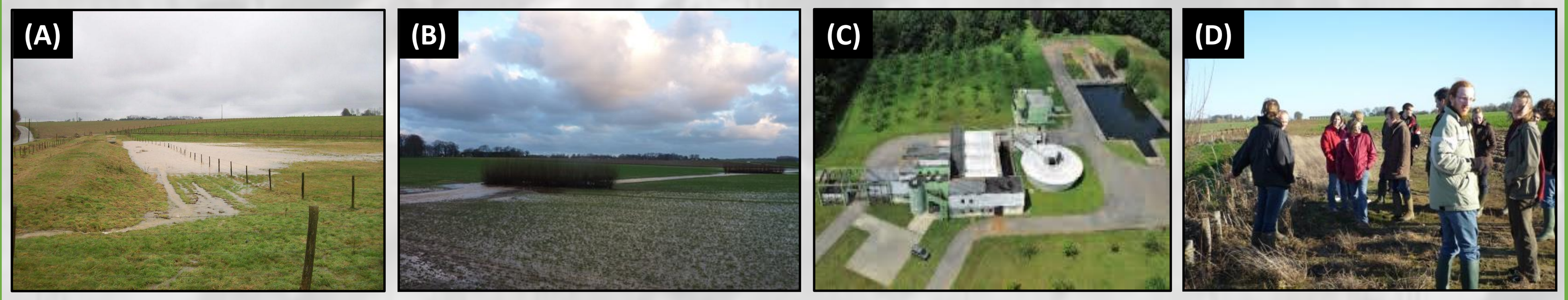


Fig.: (A) Retention pond, (B) Fascines, (C) Water treatment, (D) Animation on the field (credits: AREAS)

I. **Economic performance analysis** of assets for **flood and erosion/runoff** mitigation
II. **Provide key-elements for future public policies** through hydro-sedimentary processes and socio-economic dynamics modeling

Overview

Methods & Data

Collecting Data

Investments
(Regional funds, Water Agency, Departments)

Damages
(Regional Health Authority, French Railway, Insurances → databases + field survey)

Erosion Control Measures
(CASTOR – regional database)

Data Mining & Analysis

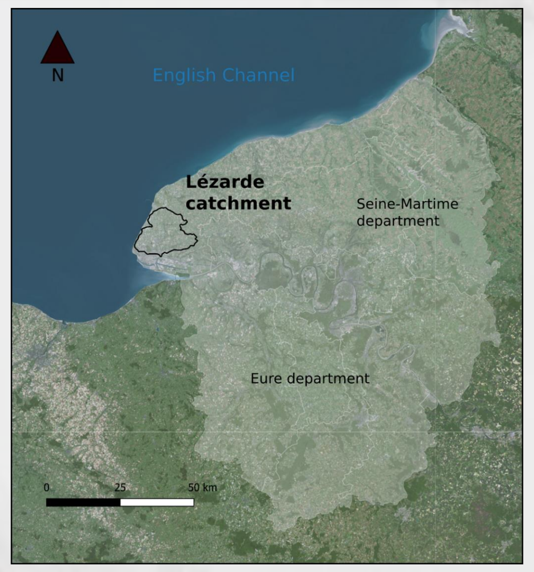
Investments :
- Extract subsidized projects linked to erosion/runoff (*n = 4086*)
- Cross-checking for co-financing
- Building typology → classification
- Estimate real volume of public investment (€)

Damages :
- Flooding/mudflow events in *CatNat (French reinsurance; n = 1379)*
- Records on drinking water prohibition (*n = 408*) → cost with local case studies
- Aggregate annual overall damage costs to transport network based on surveys

Maintenance Cost (MC) :
- Dimensions + implementation year
- Annual MC evaluation → literature review
- Adjusting for inflation

← Regional scale →

Downscaling & Flood Scenarios



i. Rainfall Frequency Analysis
- DDF curves → Meteo France (1996-2006)
- P_{10}=52 , P_{50}=75, P_{100}=87 (mm d^{-1})

ii. Building Scenarios
- Baseline (2000) and Actual (2017)
- Climate change (RCP4.5/8.5)
- Ploughing up 33% of grassland
- Best farming practices (+20% infiltration)
- More, and more, hydraulic infrastructures

(2050)

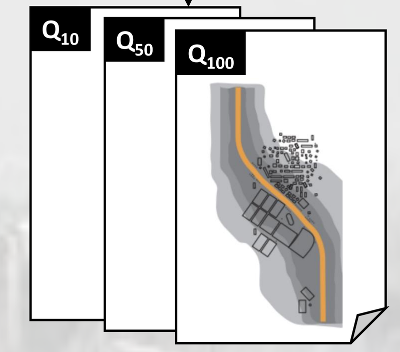
Complex Modeling Chain

Runoff/Flood Hazard modeling
- WATERSED (Landemaine et al., 2015 – BRGM)
- MIKE Hydro River 2019

Runoff/Flood Hazard exposure
- Housing/Economic activities/Public institutions
- Cultivated lands

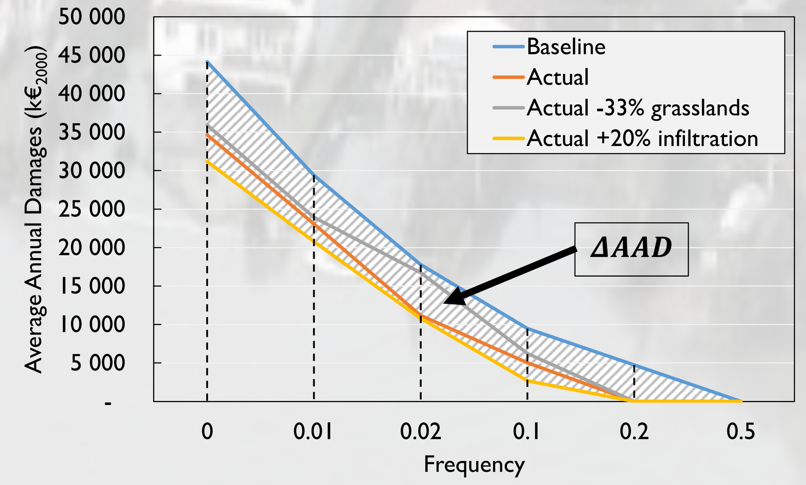
Methods:
- Land-Use database (RPG, cadastral maps, etc.)
- Google Street view + Field Survey

Damage estimation
- *Damage functions (CGDD, 2018)*
- **NEW = sediment management function**



← Catchment scale →

Cost-Benefit Analysis

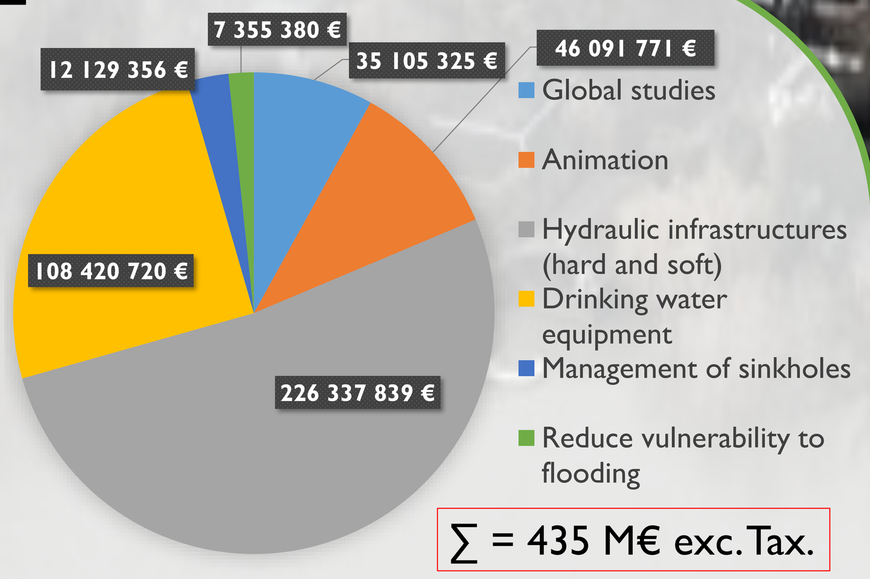


- Calculate Net Present Value (NPV; €)
- Benefit-Cost Ratio (BCR)
- Identification of sensitive parameters

Economic Overview

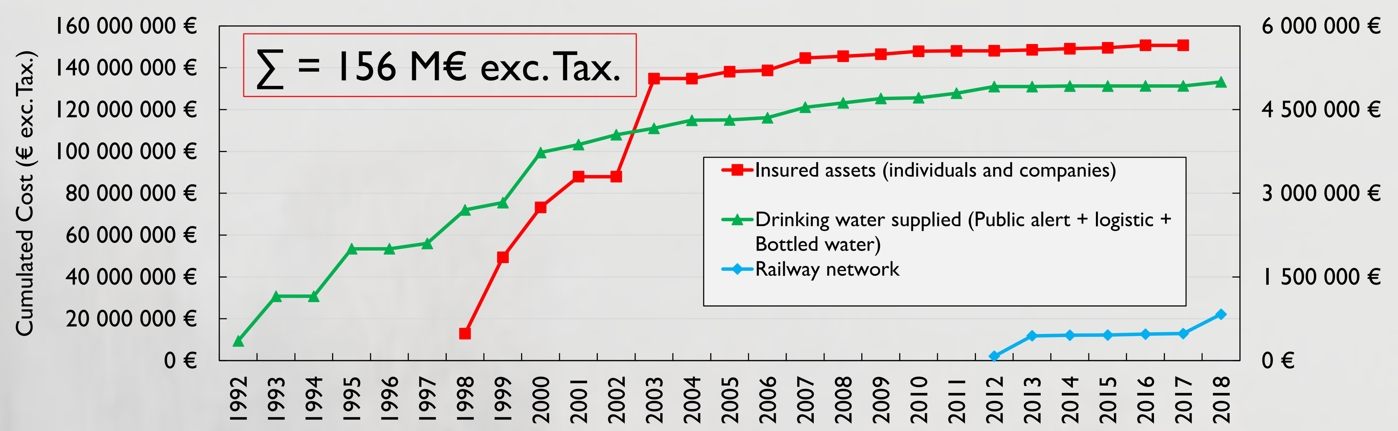
i. Investments

- Seine-Maritime and Eure departments
- Temporal frame: 2000-2017
- 4 public funders (Water Agency, Regional council, Department councils)



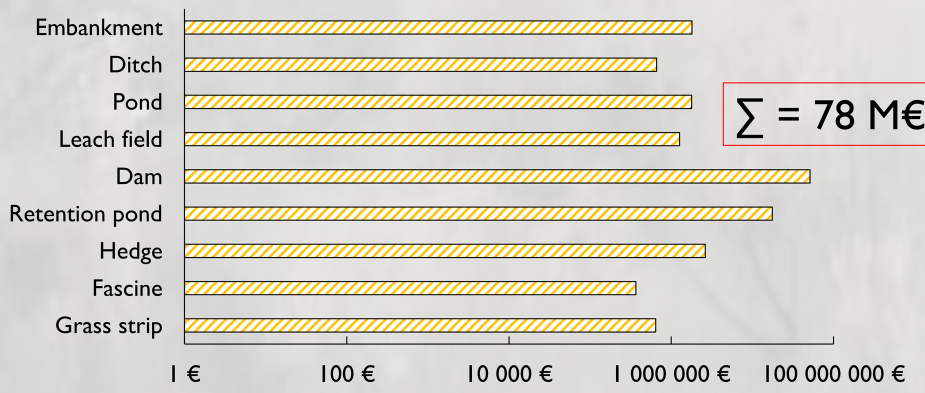
ii. Damages

- CatNat French database (Individuals = 102M€; Companies = 48M€)
- Impacts on railway network → mudflow, landslide, flooding
- Excessive turbidity in drinking water induced by erosion/runoff



iii. Maintenance

- 774 dams/retention ponds
- 211 km of hedges
- 19.2 km of fascines
- 105 ha of grass strips
- 1427 leach field/pond/ditch/embankment



Flood & Runoff Modeling

- Coupled modeling : *WATERSED* (Erosion/Runoff) + *MIKE* (Flood)
- Damages cost is influenced by both the surface of asset flooded and the height of water

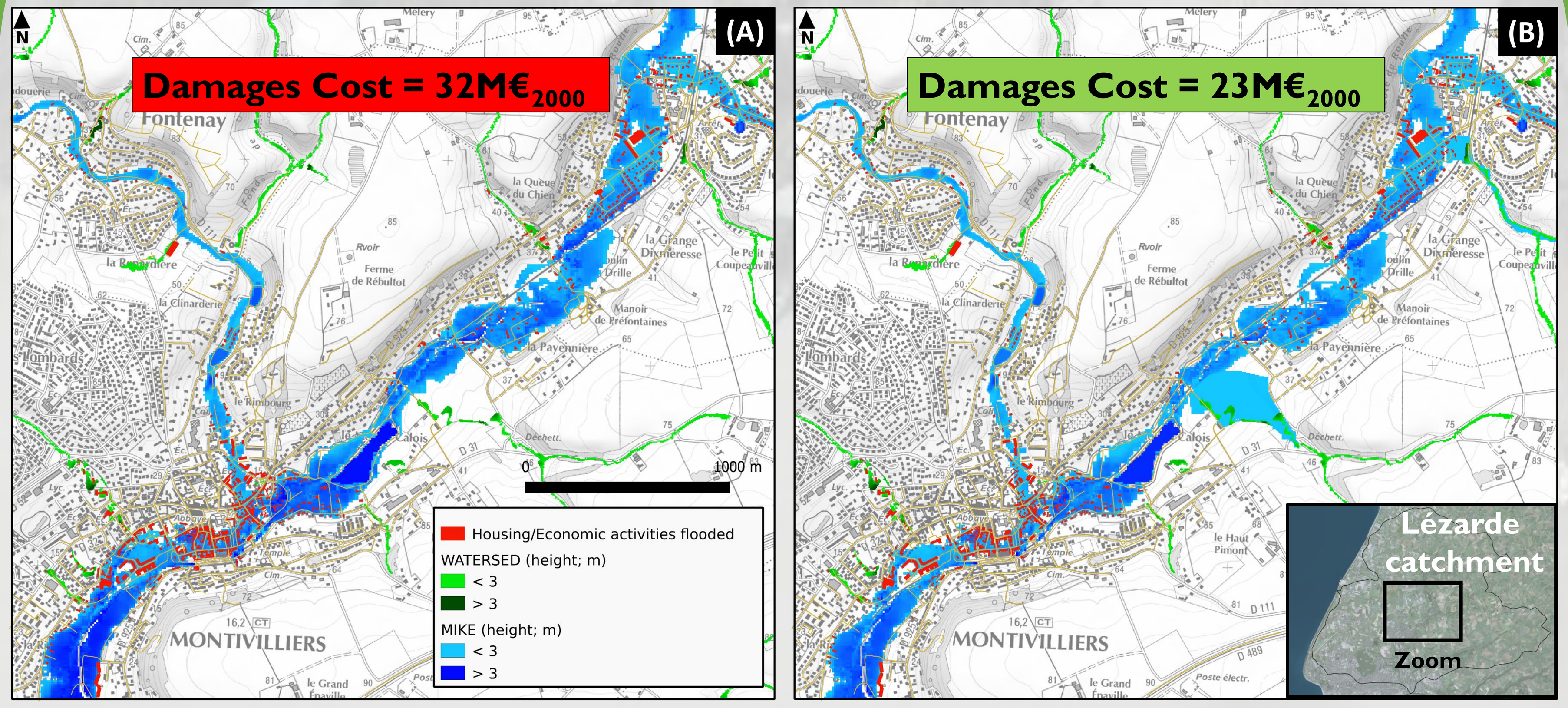
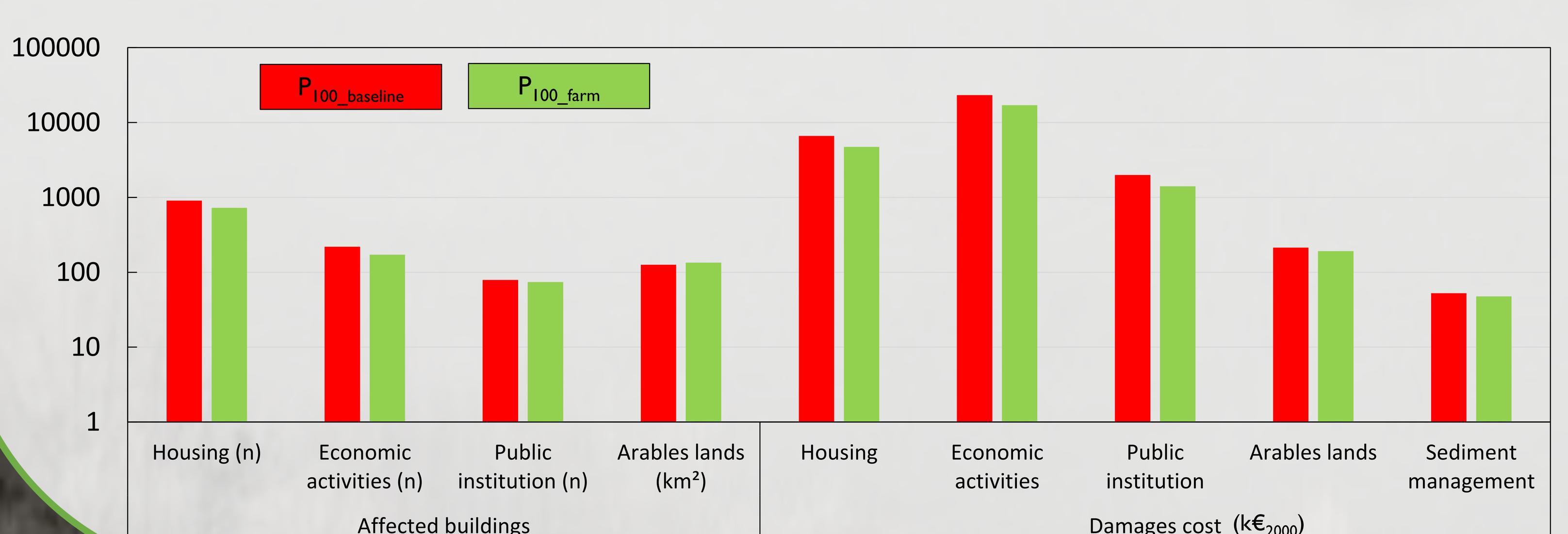
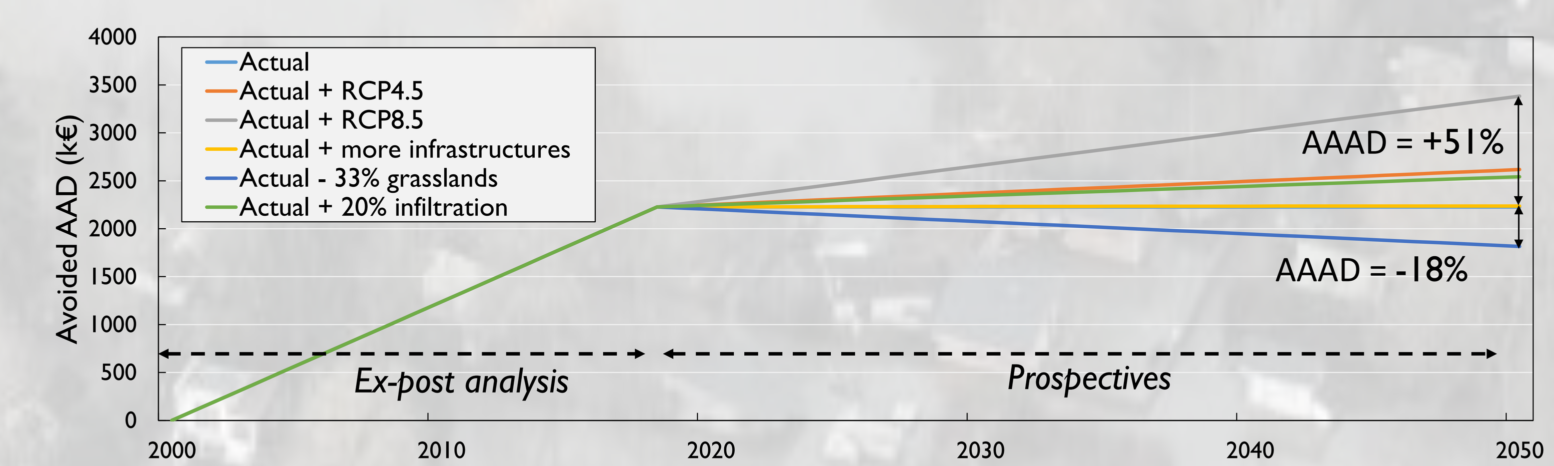


Fig.: Flood and runoff hazard modeling for the P_{100} (87 mm d^{-1}) on (A) the baseline scenario, and (B) the scenario including best farming practices by 2050. Total Damages Cost accounts for the entire catchment.



Economic Analysis of Scenarios

- Temporal analysis of Avoided Average Annual Damages (AAAD) Evolution
- NPV calculation → Economic flows discounted at 2.5%
- All costs adjusted for inflation → $€_{2000}$



	B/A	B/(A+RCP4.5)	B/(A+RCP8.5)	B/(A+G)	B/(A+F)	B/(A+I)
ΔAAD ($M€_{2000}$)	44.2	46.2	50.1	42.1	45.8	44.3
NPV ($M€_{2000}$)	15.7	17.7	21.7	13.6	17.4	11.4
BCR	1.554	1.624	1.763	1.479	1.611	1.347

*B=baseline; A=actual; G=ploughing up grasslands; F=best farming practices, I = More infrastructures

Conclusions & Perspectives

1. Hydraulic asset's BCR significantly positive → High contribution of dam/retention pond
2. Cost valuation less sensitive to sediment load reduction
3. Climate Change tends to increase the relevance of 'past' investments (RCP8.5 = +51% AAAD in 2050)
4. High sensitivity to farming practices (+20% infiltration = +14%AAAD ; -33% grasslands = -18%AAAD)
5. Farming practices improvement highly encourage by upcoming Climate Change

a. Improving the assessment of sediment load in each asset
b. Refining the cost function of sediment management
c. Integrating and Modeling sediment discharge to water treatment plant with Deep Learning algorithm (*Patault et al., 2020, In prep*)